3.0 SALMONID PROTECTION ISSUES AND EXISTING MITIGATION MEASURES

Section 3 addresses existing issues and mitigation measures for species of concern specific to the Wells Project area. This section addresses upstream and downstream passage of adult and juvenile fishes, water quality, reservoir production, predation and fish production associated with Wells Project. Existing mitigation measures related to each of these issues are also described. Proposed mitigation measures are presented in Section 5 and monitoring in Section 6 of this document.

3.1 UPSTREAM PASSAGE OF ADULT FISH

The following section addresses issues specific to existing mitigation and monitoring programs for adult upstream passage in the Wells Project area. Timing of adult passage at Wells dam is detailed in Section 2.2.1 of this document.

Wells dam has two adult fishways, one on each side of the hydrocombine (Figure 2-11), to facilitate upstream passage of adults past the project. Adult counting stations are located in the vicinity of the exit of each ladder. Section 3.1.1 addresses issues and mitigation for adult passage at the dam, and Section 3.1.2 addresses issues and mitigation for adult passage through the reservoir. Generally, adults of species of concern are present in the project area from May through November, although adult steelhead may be present year-round.

3.1.1 Upstream Passage at Wells Dam

The term adult fishway is defined in this document as all structural and operational components of adult fish passage facilities at the projects including entrances, collection systems, ladders, water supply system, attraction jets, counting and brood stock collection facilities and exits. A full description of the structural and operational aspects of the Wells adult fishways is provided in Sections 2.3 and 2.4. Potential biological issues related to upstream passage of adult fish via the fishway facilities include delay, adult fallback and pre-spawning mortality. The following is a summary of these issues as they apply to Wells dam.

Existing Issues

Upstream passage facilities at the Wells Project are operated in accordance with criteria specified in a 1990 Settlement Agreement (Federal Energy Regulatory Commission 1990). The fishways are inspected by representatives of the state and federal fishery agencies, tribes and the Fish Passage Center (FPC). Modifications to address delay or mortality are implemented in agreement with the Wells Project Coordinating Committee (WCC). Recently, a major study of adult migration in the project area has helped to further identify issues and concerns with passage of adult chinook at the project (Stuehrenberg et al. 1995). Discussion of adult upstream passage involves physical and behavioral aspects of fish, and physical and hydrologic characteristics of the facilities. Terms used to describe features of the adult collection and fishway facilities used in this section are defined as follows (in order of their use):

RDSE	=	Right downstream entrance
LDSE	=	Left downstream entrance
RSE	=	Right side entrance
LSE	=	Left side entrance

<u>Delay</u>

Migrational delay of adult salmonids has the potential to increase mortality by increasing exposure to harvest or disease and to cause reductions in adult energy stores or spawning ability. Stuehrenberg et al. (1995) indicate that adult spring, summer, and fall chinook salmon quickly located the Wells fishway entrances in 1993 (Table 3-1). The time between tailrace arrival and first entry into the fishway at Wells was found to be lower than at the other four mid-Columbia project fishways. Stuehrenberg et al. (1995) concludes that the rapid entrance location time at the Wells fishways is a result of the low number (four) of entrances at the project and the proximity of the entrances to the fishways.

Median total passage time for adult spring chinook at Wells dam in 1993 was 28.5 hours, ranging from 2.9 to 1,396 hours (Table 3-1) (Stuehrenberg et al. 1995). The median time required for spring chinook to locate the Wells fishway entrances was less than one hour (Table 3-1). The median time required for spring chinook to move through the collection system and locate ladders was 26.8 hours. Median passage times through the right bank and left ladders were 2.2 and 2.1 hours, respectively (Table 3-1) (Stuehrenberg et al. 1995).

Median total passage time for adult summer chinook at Wells dam in 1993 was 46.9 hours with a range of two to 1,108 hours (Table 3-1) (Stuehrenberg et al. 1995). Summer chinook required a median time of only 0.4 hours to locate entrances, and required a median time of 33.3 hours to negotiate the collection channel system and enter the ladder. Once in the ladder, median time for passage through the right and left bank fishways was 2.6 and 2.7 hours, respectively (Table 3-1) (Stuehrenberg et al. 1995).

Median total passage time for adult fall chinook at Wells dam in 1993 was 45.6 hours with a range of 4.8 to 828 hours (Table 3-1) (Stuehrenberg et al. 1995). Fall chinook required a longer time to locate entrances and ladders than either spring or summer chinook, requiring a median time of 2.4 hours from first entry into the fishway to the last collection-channel exit and location of the ladder. Once in the ladder, median time for passage through both right and left bank fishways was 2.4 hours (Table 3-1) (Stuehrenberg et al. 1995).

Table 3-1. Median passage travel time of radio-tagged chinook and sockeye salmon passing over Wells dam in 1993

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Median total passage time for adult sockeye salmon in 1992 was 31.2 hours with a range of 7.2 to 444 hours (Table 3-1) (Swan et al. 1994). Sockeye required a median time of 2.4 hours from arrival to first entry into the fishway; the time required to locate the ladders is not available. Once in the ladder, median time for passage through the right and left fishways was 4.8 and 7.2 hours, respectively (Table 3-1) (Swan et al. 1994).

The efficiency of the Wells fishway entrances varies by entrance location, species, and race/deme. For spring chinook, the right downstream entrance (RDSE) and the left downstream entrance (LDSE) showed relatively high numbers of net positive entrances, i.e., more fish entering than exiting the fishway. The right side entrance (RSE) showed slight net positive entrances and the left side entrance (LSE) showed slight negative net entrances, i.e., more fish exiting rather than entering the fishway. The negative net entrances at the LSE indicate that spring chinook were entering through the LDSE and exiting through the LSE. Spring chinook used both fishways about equally, and most frequently entered through the LDSE, followed by the RDSE (Stuehrenberg et al. 1995).

The majority of summer chinook (90%) used the left fishway and most frequently entered through the LSE, followed by the LDSE. The LDSE showed high net positive entrances with the LSE, RDSE, and RSE showing very low net positive entrances (Stuehrenberg et al. 1995). Fall chinook most frequently used the left fishway (61.5% of the time), and most frequently entered through the LDSE, followed by the RDSE. All entrances showed net positive entrances, with the LDSE and LSE highest (Stuehrenberg et al. 1995).

Sockeye salmon most frequently used the left fishway (65% of the time) (Swan et al. 1994). About two-thirds of sockeye successfully passing through the facilities entered via the end entrances, LDSE and RDSE, and about one-third entered via the side entrances, LSE and RSE. Only the LDSE had strongly net positive entrances. The right fishway entrances (RDSE and RSE) and the LSE all had net negative entrances; although it may not be possible for both the RDSE and the RSE to have net negative entrances, the right fishway was nonetheless much less efficient than the left fishway. Sockeye adults which successfully negotiated the fishway made an average of 24.5 and 41.5 entrance attempts at the left and right fishways, respectively (Swan et al. 1994).

Based on these results, the side entrances (LSE and RSE) were inefficient at passing spring and summer chinook and sockeye, but were effective entrances for fall chinook adults. The LDSE was consistently effective at passing all four species, and the RDSE was effective for spring and fall chinook passing the Wells Project. Therefore, reducing the number of entrances, which may be effective at other mid-Columbia projects, may not significantly improve adult upstream passage time for chinook salmon at Wells dam. More information may be needed to explain the high number of entrance attempts and net negative entrances for sockeye at the right fishway.

Adult Fallback

Adult fallback is defined as voluntary or involuntary downstream movement of upstream migrating adults across a dam. Adult fallback information is available for spring, summer and fall chinook and for sockeye salmon from radio-telemetry studies at Wells dam (Swan et al. 1994; Stuehrenberg et al. 1985). No detailed radio-telemetry information regarding adult fallback is available for steelhead trout at Wells dam.

Stuehrenberg et al. (1995) reported that 3.6 percent of radio-tagged spring chinook adults (two of 56) experienced fallback at Wells dam in 1993. Both of these adults were last located in spawning areas downstream from Wells dam. Fourteen percent of summer chinook adults (14 of 98) fell back over the project. Six of these fish later reascended the adult fishway, two were last located in spawning areas downstream from Wells dam, four were last located in the Wells tailrace area and two entered the Wells fish hatchery. Twenty-one percent of radio-tagged fall chinook adults (11 of 52) fell back over Wells dam; one of these adults reascended the fishway, six remained in the tailrace, one was harvested downstream of the project, and three returned to Wells fish hatchery. Stuehrenberg et al. (1995) stated that they could not differentiate adults spawning in the mainstem from mortalities. Giorgi (1992) documented fall chinook spawning in the Wells tailrace. In 1992, 13 percent of radio-tagged sockeye adults (nine of 69) at Wells dam fell back at least once; all fallbacks occurred during periods of spill, ranging from 4.1 to 7.6 percent of total flow at the project (Swan et al. 1994). Of nine adults that fell back, two fell back twice. Only one fallback did not reascend the project.

Stuehrenberg et al. (1995) could not determine whether or not the adult summer and fall chinook that fell back and did not reascend the fishway may have "overshot" their intended destinations and fell back actively across the dam as they headed back downstream. They offered no evidence that these fish might have otherwise migrated past Wells dam and spawned at some upstream location. Overall, the incidence and frequency of fallback at Wells dam appears to be consistent with fallback at other Columbia Basin mainstem dams (Stuehrenberg et al. 1995).

Adult Losses at the Project

Interdam loss, defined as disappearance between two hydropower projects, is one component of pre-spawning mortality of adult salmonids, as are other factors such as disease, harvest, etc. Pre-spawning mortality, in turn, is defined as mortality between the time of measured escapement and the time of egg deposition (Chapman et al. 1991). Interdam loss can be further differentiated into losses at the dam, in the reservoir and in the tailrace area.

Losses of adult salmonids that may take place at Wells dam have not been enumerated. There are no known causes of direct adult mortality at Wells dam. Known causes of adult mortality that could potentially occur at Wells dam are TDG supersaturation, tailwater temperature, and mortality associated with fallback over the spillway or through the turbines. The Stuehrenberg et al. (1995) study of chinook fallback at Wells dam could not differentiate adult mainstem spawning from mortalities.

Sixty-one tagged fall chinook were last recorded in the Wells dam tailrace, seven were last recorded in Wells reservoir in the vicinity of the dam, and two were last recorded in the Wells dam area (Stuehrenberg et al. 1995). The fate of the fall chinook adults last recorded in the tailrace is not known, although they may have spawned there. It is not possible to compute percentages of adults either lost at the project or that spawned below the project from the data as presented in Stuehrenberg et al. (1995). Swan et al. (1994) observed that 90 percent (71 of 79) of radio-tagged adult sockeye successfully passed over Wells dam. The fates of the eight adults that did not pass the project are not known. Little data are available concerning adult losses of steelhead at Wells dam.

Previous and Existing Mitigation Measures

Migration delays were noted during the first few years of fishway operation (Meekin 1967). Large schools of adult salmon were observed in the tailrace, apparently searching for fishway entrances. During this period, turbines installed to pump water through the fishways were inoperative, considerably reducing adult attraction flows. Total blockage was never observed, but delays occurred. During 1967 and 1968, while equipment was being upgraded, fishway operation was alternated to allow upgrading of the system. Several other reasons were cited by Meekin (1967) for delays observed in fish passing through the Wells fishways.

Head differentials at fishway entrances also required modification during the first years of fishway operation as the amount of attraction flow was insufficient to attract adults. The original entrance head differential of one foot was modified to operate at one and one half feet, which improved adult attraction. Lights were also installed in internal portions of the fishway in order to aid adults in negotiating the ladders.

The fishway facilities at the Wells Project are considered to be relatively successful (Fish Passage Center 1992, 1993). Fishway-operating criteria are modified on an annual basis in the agreement with the WCC. The facilities are inspected annually by the FPC. Reports based on these inspections have been produced annually (Columbia Basin Fish and Wildlife Authority 1994) for 11 years and have contributed to the development of fishway operating criteria (see Section 2.4.2) and the fine-tuning of fishway operations. Operating criteria are included in the 1990 Settlement Agreement (Federal Energy Regulatory Commission 1990).

Effectiveness of Existing Mitigation

Relative effectiveness of Wells fishways has been assessed by comparing their performance with other fishways in the Columbia and Snake Rivers. The chinook salmon radio-telemetry study by Stuehrenberg et al. (1995) is the only work that includes a systematic evaluation of several mid-Columbia fishways. Based on these results, it is apparent that the Wells fishways are the most efficient of the mid-Columbia fishways with respect to the attraction of fish to the fishway entrances. The median time required for adult chinook to pass through the collection system and enter ladder sections of the Wells fishways was among the highest of the mid-Columbia fishways. Data from Stuehrenberg et al. (1995) indicate that spring and fall chinook salmon took an average amount of time, and summer chinook took longest, to negotiate the adult fishway at Wells dam as compared to the other four mid-Columbia projects . The median total passage time at Wells dam for spring and fall chinook was average for the fishways at mid-Columbia projects, but passage time for summer chinook was highest of the mid-Columbia fishways .

Since Swan et al. (1994) evaluated adult sockeye passage only at Wells dam, a comparison between projects is not possible. However, based on the results for summer chinook, which pass Wells dam at approximately the same time of year, sockeye took less time to pass the project, but fell back more often. Adult sockeye appear to pass the project more frequently via the right fishway than the left fishway.

It is extremely difficult to isolate variables affecting the success of the Wells fishway facilities in passing adult migrants upstream from the tailrace to the forebay. Any evaluation of fishway effectiveness is complicated by behavioral and life history variability of anadromous fish stocks, and by a general lack of information on migration and spawning behavior in the mid-Columbia River reach. It is reasonable to expect that mitigation addressing chinook salmon delays, fallback and losses at the project and reservoir will have similar effects on adult passage of other salmonid species.

Ongoing Monitoring

The state and federal fishery agencies, tribes and the FPC conduct annual inspections of the fishway facilities at Wells dam. The WCC coordinates mitigation measures that result from any problems identified during the inspections. No surveys track fall chinook spawning in the tailrace area at the present time, therefore adults that may spawn in the tailrace are not included in estimates of interdam loss of adult fall chinook that may be attributable to Wells dam.

3.1.2 Upstream Reservoir Passage

Once adults pass the dam, they navigate the reservoir to reach tributary spawning areas. Issues regarding reservoir passage include travel time and survival of adults. Wells reservoir has two major tributaries, the Methow and Okanogan Rivers, that are used for spawning. The federal project upstream from Wells dam, Chief Joseph dam, has no adult upstream passage facilities, and, therefore, adults passing the Wells Project are destined for spawning areas in the tributaries to Wells reservoir, the reservoir itself, or the Chief Joseph tailrace. Since counting takes place only at Wells dam it is not possible to enumerate losses of adults between Wells dam and the various spawning destinations. Passage of adult salmonids through reservoirs has been documented in other areas of the Columbia River Basin (Bjornn and Peery 1992; Bjornn et al. 1994; Bjornn et al. 1995). Only two studies, Stuehrenberg et al. (1995) and Swan et al. (1994) have been performed on the mid-Columbia River reservoirs. .

There is little evidence to suggest significant impacts on adult migration and pre-spawning mortality occur in the mid-Columbia River reach reservoir environment. Bjornn and Peery (1992) included information from mid-Columbia and other run-of-river reservoirs in their comprehensive review of the effects of reservoirs on adult salmon. Based on the available information, they concluded that run-of-river reservoirs had minimal effect on migrating adults. Adult salmonids generally pass through these reservoirs at similar or faster rates than they do in the naturally flowing river. There is no evidence of serious disorientation, wandering, straying or mortality associated with reservoir conditions.

Adult Reservoir Passage Issues

Travel Time

Travel time of adult salmonids through both impounded and free-flowing reaches is relatively well known in the Columbia River Basin. Adult salmonids travel rates range from less than seven to 17 miles per day in unimpounded reaches of the lower Columbia and Snake Rivers. Travel rates of adult spring and summer chinook and sockeye through Wells reservoir range from 2.2 to 7.2 miles per day (Stuehrenberg et al. 1995; Swan et al. 1994). Adult chinook slowed their speed of migration through the mainstem reservoirs as they neared their natal streams and hatcheries (Stuehrenberg et al. 1995). The observed slower travel rates through the Wells reservoir are probably the result of the proximity of the fish to their spawning streams as well as delays in upstream migration due to elevated temperatures in the Okanogan River. Typically by the middle of July the Okanogan River exceeds 23°C (75°F) and as such precludes the entry of adult summer and fall chinook, summer steelhead and sockeye (Chapman et al. 1995b).

Travel times of spring and summer chinook and sockeye salmon through Wells reservoir to the Methow and Okanogan Rivers are presented in Table 3-1. Spring chinook adults took a median 30.9 hours to travel from Wells dam to the mouth of the Methow River (eight miles), a rate of 6.2 miles per day (Stuehrenberg et al. 1995). Spring chinook took a median time of 270.4 hours to travel the 69 miles to the mouth of the Okanogan River, an average of 6.1 miles per day. However, summer chinook adults, for the most part, traveled to the Okanogan River mouth, held near the mouth, then returned to the Methow River 61 miles downstream. The median travel time to the Okanogan River was an extremely rapid 24.6 hours, and the median total time to travel the 130 miles from Wells dam to the Methow River via the Okanogan River was 434.2 hours, a rate of 7.2 miles per day (Stuehrenberg et al. 1995). The authors do not present travel times for fall chinook to their destinations above Wells dam.

Twenty adult sockeye radio-tagged by Swan et al. (1994) took a median of 33.5 days to travel 24 miles from Wells dam to Monse at RM 6 of the Okanogan River (range of eight to 43 days), an average of 0.72 miles per day. Swan et al. (1994) note that the temperature in the Okanogan River was above the level which sockeye would enter the river until August 23; only three fish entered the river before this date.

Interdam Loss

As stated earlier, interdam loss has two components: loss at the project and loss in the reservoir. Due to lack of comprehensive fish counts in the Methow and Okanogan Rivers for the species of concern, it is not possible to isolate loss in the project. Loss in other reservoirs varies by time of year, species, and project. Loss rates for spring, summer and fall chinook in the reservoir cannot be calculated from Stuehrenberg et al. (1995), since the fate of fish last tracked in Wells reservoir and below Chief Joseph dam is not clear. The authors could not account for eight spring chinook below and six above Wells dam, and two summer chinook below and two above the project. Seven fall chinook were last located in Wells reservoir near Wells dam; one was last tracked at the mouth of the Okanogan River, where it may have spawned. Seven were last tracked in Wells reservoir in the vicinity of the Bridgeport Bar, and may have spawned there. Sixty-one fall chinook were last located in the Wells tailrace and may have spawned in the tailrace, but the authors stated that they could not distinguish adult mainstem spawning from mortalities.

Most adult sockeye salmon radio-tagged by Swan et al. (1994) were destined for the Okanogan River. Of the 69 adults that passed over Wells dam, 29 (42%) were accounted for at Zosel dam on the Okanogan River. It is not possible to determine the fate of the remaining adults; they may have either moved upstream to the base of Chief Joseph dam, entered another tributary to Wells reservoir, remained in the lower Okanogan River or remained in Wells reservoir. Another explanation for the low detection percentage at Zosel dam is that some tags experienced antennae problems and were not able to be tracked.

These low numbers of unaccounted-for adult chinook suggest that the loss rate of chinook in Wells reservoir is low, and may be within the 3 to 5 percent rates calculated for other reservoirs. The loss rate of sockeye salmon between Wells dam and Zosel dam may be very high, but the causes of this loss (such as lethal water temperature in the lower Okanogan River, passage loss at Zosel dam, wandering, or reservoir effects) cannot be isolated. However, a radio-tag study of adult sockeye salmon conducted in 1997 (Alexander et al. 1998) showed that 83 percent of in-river migrants that passed Wells dam reached the spawning grounds in Canada.

Previous and Existing Mitigation Measures

Full and complete mitigation for anadromous fish losses at the Wells dam, including upstream migrating adults, has been stipulated in the 1990 Settlement Agreement (Federal Energy Regulatory Commission 1990). No additional mitigation is required under the settlement agreement for the loss of adults in Wells reservoir. There is no evidence to suggest that adverse impacts on adult migration and subsequent pre-spawning survival occurs in Wells reservoir.

Effectiveness of Existing Mitigation

No mitigation is required for reservoir effects. Adult passage rates through Wells reservoir are influenced by the proximity of the reservoir to spawning streams and the ambient temperature encountered by adults in those tributaries, rather than the presence of or conditions in Wells reservoir.

Ongoing Monitoring

Monitoring efforts specifically designed to evaluate reservoir-related impacts on adult migrants in Wells reservoir are unnecessary due to rapid adult passage rates.

3.2 DOWNSTREAM PASSAGE OF JUVENILE FISH

3.2.1 Downstream Passage at Wells Dam

Existing Concerns and Issues

Fish migrating downstream through the mid-Columbia reach encounter a series of reservoirs and dams on their journey to the Pacific Ocean. Potential mechanisms that allow fish to pass from the upstream to the downstream side of any dam include the following:

- passage through a turbine;
- passage over a spillway, through a sluiceway or locks.
- passage through a permanent fish bypass system;
- passage in a downstream direction through ancillary dam facilities, such as the adult fishway facilities; or
- collection of fish on the upstream side of the structure followed by transport and release on the downstream side.

Issues for each of these potential methods of downstream dam passage as they relate to the Wells Project are presented in this section.

Turbine Passage

Turbine-related juvenile fish mortality includes both direct and indirect components. Direct mortality can result from mechanical damage, pressure-induced damage (including cavitation) and damage due to the shearing action of water present when two proximal planes of water exist with opposing vectors. Indirect mortality can result from conditions such as stress, disorientation and backroll entrapment which are not normally lethal in themselves, but which may result in increased risk of predation or injury during subsequent downstream migration.

Fundamental relationships as they relate to turbine passage and mortality have not yet been established between physical variables such as turbine criteria and hydrographic conditions, and biological variables such as species, size, condition, and health (Iwamoto and Williams 1993). However, based on current understanding, it is often possible to suggest whether a particular feature will have positive or negative impact on turbine mortality. In the discussion that follows, project-specific features of the Wells dam turbines are noted which may affect turbine mortality.
System survival studies conducted on the mid-Columbia reach during 1982 and 1983 examined spring chinook survival through two reaches: Pateros (at the head of Wells reservoir) to Rock Island, and Rock Island to Priest Rapids (McKenzie et al. 1984a, 1984b). The Pateros to Rock Island reach involved passage through three projects (Wells, Rocky Reach and Rock Island) and resulted in survival estimates of 64 percent in 1982 and 60 percent in 1983. Based on this information and making the gross assumption that mortality rates are approximately equal through each project, the authors estimated the single project mortality for Wells, Rocky Reach and Rock Island at about 13 percent in 1982 and 16 percent in 1983. These studies made no specific estimates as to what portions of the project mortality were associated with direct and indirect turbine mortality, reservoir effects, or other factors involved with project passage. The hatchery-based compensation program developed as part of the 1990 Wells Long Term Settlement Agreement assumes an initial total project mortality rate of 14 percent.

A study attempting to measure turbine and spillway mortality specifically for Wells dam was conducted in 1980 following two years of pilot studies (Parametrix 1986). Whereas the 1978 pilot study suggested direct turbine mortality was very low, the 1980 study results estimated Wells turbine mortality at 16 percent. However, several serious assumption violations were observed during the 1980 study. Left brand and right branding positions were used during this study and the recapture and subsequently the survival estimates generated from the two different mark groups was very different. Residualism during this study varied greatly between the two different brand types which may have adversely effected the recapture estimates for the various groups. In addition the pre-release, post-marking survival of the two brands groups was also very different. Survival estimates generated from these two different marking groups ranged from a high of 96 percent to a low of 6 percent.

All of the turbine runners at Wells dam were replaced between 1988 and 1990, and there have been no turbine mortality studies conducted at Wells since that time that would reflect the improved turbine passage conditions. Recent studies conducted at Rocky Reach dam measured mortalities of about 6 percent for Kaplan turbines (RMC and Skalski 1994a, 1994b). A review of nine turbine passage studies conducted for lower Columbia and Snake Rivers dams found that Kaplan turbine passage mortality estimates varied from 2 to 20 percent (Iwamoto and Williams 1993).

Turbine intakes at Wells dam are located quite deep in the water column as compared to most mid-Columbia River hydroelectric facilities, primarily due to its hydrocombine design which places the turbine intakes below the spill bay intakes. The top of each Wells turbine intake is located 77 feet below the normal headwater surface elevation, and the bottom is at 135 feet below the surface. Vertical fish distribution studies conducted at Wells have shown that most downstream migrants approach the dam above the spill/turbine intake boundary (Johnson et al. 1992). Fish entering the turbine intakes tend to travel within the upper two-thirds of the intake, and very few fish travel along the bottom of the intakes (Figure 3-1).

Based on a 1991 study examining the horizontal distribution of fish passing Wells turbines, higher turbine passage rates occur at the east end of the dam during the spring migration period (Kudera et al. 1992). During the summer migration period, however, turbine passage rates show no distinct pattern and instead fluctuate across the width of the dam. There is no evidence to suggest that prioritizing the order of use of Wells turbines would enhance downstream migration.

The diel distribution of turbine passage rates measured during the spring migration period show greater passage rates in the hours between 6 a.m. and noon, about twice as high as passage rates during the late afternoon (Kudera et al. 1992). During the summer migration period, passage rates were greatest between 10 a.m. and 4 p.m., and more than twice as great in the slow period between midnight and 6 a.m. (Kudera et al. 1992). It is interesting to note that the summer passage rates of subyearling summer/fall chinook appear to be directly related to the daily discharge fluctuations at Wells dam. This relationship may be caused by either passive entrainment of these fish through the project or it may be caused by a behavior response by the fish tied to the increased in river flow. This pattern might be related to the fact that the bulk of the summer migrants at Wells dam are ocean-type chinook, as opposed to the stream-type migrants which predominate the spring run, and due to their reduced mobility, the subyearlings may be more strongly influenced by the flow patterns and hydraulic conditions at the project.

Survival of juvenile fish through turbines has been generally found to correlate with turbine operating efficiency (Bell 1981). However, an analysis by Eicher (1987) concluded that the data set is too small to draw any direct or statistically significant relationship between turbine operating efficiency and mortality. Some researchers speculate that fish survival is probably best at peak turbine efficiency (Bell 1981), while others believe that settings beyond the peak offer better conditions for fish passage (Sheldon, pers. comm., 19 June 1995). The federal projects on the lower

Figure 3-1. Vertical distribution of chinook and sockeye from simultaneous fyke net samples in a bypass intake at Wells dam during spring 1985

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Columbia and Snake Rivers attempt to operate within 1 percent of peak efficiency during the juvenile migration period, but the precise benefits of operating within this range are unknown, especially in light of indeterminate excursions outside of the range (NMFS 1995a).

The Kaplan turbines at Wells have high operating efficiencies over a broad flow range. The 10 units are operated under joint load control; that is, the settings and resultant efficiencies are the same for all units that are operating, except during the brief periods when a unit is just coming on or off line. Based on the immediate power demands and flow conditions at the dam, the Wells system will automatically adjust the wicket gate openings and blade angles to provide the best turbine efficiency under the given conditions. The automated settings are based on model testing information that has been verified and updated using the Winter-Kennedy index testing method. Consequently, typical turbine operations at Wells dam maintain high efficiencies under most conditions.

Dam Spillway Passage

Flow over the Wells dam spillway may occur either as bypass spill from operation of the smolt bypass system, or as forced spill due to flows that exceed the 200 kcfs powerhouse capacity. Characteristics of spill required to operate the smolt bypass system are discussed in Section 2.4.3. Issues involving spillway passage at Wells dam are related to predation in the tailrace on juveniles passing over the spillway (addressed in Section 3.5), increases in TDG and associated GBT in juvenile migrants (addressed in Section 3.3) direct and as well as indirect mortality resulting from passage through the spillways.

Juvenile Bypass System

The Wells juvenile bypass system began full-scale operation in 1989 following nine years of research and development. Performance criteria for the bypass system set forth in the 1990 Wells Dam Settlement Agreement call for a fish passage efficiency (FPE) of at least 80 percent for the juvenile salmonid spring migration and an FPE of at least 70 percent for the juvenile salmonid summer migration. Fish passage efficiency is defined as the ratio of fish passing through the bypass system to the sum of fish passing through the bypass system and turbines (Federal Energy Regulatory Commission 1990).

The vertical distribution of juveniles in the forebay strongly effects the fish passage efficiency of the Wells bypass system. Hydroacoustic data collected from 1981 to 1983 indicates that 90 percent of fish approaching the dam during the day are located above the spillway/turbine intake boundary, and that 55 percent are above during the night. Fyke nets extending the full depth of the bypass and turbine intakes show chinook and sockeye migrants to be above the boundary 94 percent of the time during the day. At night, the numbers above the boundary fall to 80 percent and 63 percent for chinook and sockeye, respectively (Johnson et al. 1992). It should be noted, however, that these distribution data were collected prior to installation of the bypass system, and that the current configuration and operation of the bypass system could impact the vertical distribution.

The horizontal distribution of downstream migrants in relation to the location of bypass baffle openings will also impact the fish passage efficiency of the system. In a 1991 study, the spring migration period showed higher passage rates for those bypass units located at the west and center portions of the spillway (Kudera et al. 1992). During the summer migration period, the bypass passage rates were again generally higher on the west side and center portion.

Each bypass unit at Wells has a baffle opening 16 feet wide by 73 feet high that results in an average velocity through the opening of about 2 feet per second. The flow net associated with baffle openings has no sharp transitions. There is no evidence to suggest outmigrating smolts strike the baffles during passage.

Once past the baffles, passage through the smolt bypass system is identical to passage over the spillway. Fish which pass through Bypass Units S4, S6 or S8 exit the bypass system via bottom spill. Bypass Units S2 and S10 have the option of spilling over the ice and debris sluice gates or using bottom spill.

<u>Ancillary Passage Routes</u>

Several support functions at Wells dam are supplied by reservoir water and discharge to the downstream side of the dam, resulting in a potential passage route for fish to pass the dam. These functions include the gravity flow and supplemental water supplies for the fishways, attraction jet supplies, and supplies for the fish pump turbines. It is estimated that these functions consume less than half of one percent of the total project discharge. Intakes for the noted supplies are equipped with trashracks.

<u>Collection and Transport of Juvenile Fish</u>

An alternative strategy for downstream dam passage involves collecting juvenile migrants on the upstream side of a dam and transporting them past one or more dams to be released. While this mechanism avoids the potential of direct impacts caused by turbine, spillway, or ancillary routes of passage, the mortality that results from collection and transportation must be taken into account. Erho et al. (1995) assessed the survival of steelhead that were acclimated in the Methow River and then transported by truck to below Bonneville Dam. These fish showed very high transport benefit survival, as evaluated by adult returns, in lower river areas. However, the fish showed little or no net increase in survival rates and in several cases decreased adult survival rates to areas upstream of Wells Dam. Due to the observed problems of straying and due to the lack of navigation locks in the Mid-Columbia River, barging and other transportation activities, similar to the ones that occur in the Snake River, are not considered viable mitigation options at this time.

The existing bypass system currently passes approximately 90 percent of the outmigrants (Skalski 1993). Barge transportation is not an option from Wells dam since there are no navigation locks at the downstream Rocky Reach, Rock Island, Wanapum and Priest Rapids dams.

Previous and Existing Mitigation

The Wells Project has implemented many programs to minimize and mitigate the impact of downstream dam passage on juvenile fish migrants. These actions, described in detail in the following paragraphs, involve the following:

- fish passage spill;
- turbine improvements and operations;
- smolt bypass systems; and
- fish production as mitigation.

Fish Passage Spill

In 1987, by agreement of the Mid-Columbia Coordinating Committee, fish passage spill at Wells dam was terminated and replaced with operation of the juvenile bypass system (Federal Energy Regulatory Commission 1990). Water spilled for the express purpose of aiding juvenile fish passage past the dam is now associated with operation of the bypass system, and as such is referred to as bypass flow. Details regarding installation and start-up operation of the juvenile bypass system are described in Sections 2.3.3, 2.4.3 and 3.2.1 of this document.

Turbine Improvements and Operations

In 1981, a Kaplan turbine runner linkage failure in Turbine Unit 7 led to the discovery that the Kaplan runner blade adjusting mechanisms at Wells were susceptible to progressive fatigue failure. To reduce the risk of additional failures, the runner blades of nine of the 10 turbines were welded into a fixed position, resulting in reduced operating efficiencies. With a remaining design life of at least 20 years, the DCPUD evaluated several alternatives for the runners, including replacement of some or all of the runners. Beginning in 1984, the DCPUD embarked on a program to design, test, and construct 10 new high efficiency Kaplan runners with adjustable blades. The new runners were installed between 1988 and 1990 (Pflueger, pers. comm., 24 February 1995).

Model testing of the new runners indicates a maximum efficiency of 94.6 percent at 68 feet net head, which is substantially higher than the maximum efficiency of the original runners. The new runners also have smaller clearances between the runner blade and discharge ring and between the hub and blades. Based on the current understanding of causal factors in turbine mortality, these factors may contribute to safer passage through the Wells turbines as compared to the original construction.

The Wells Dam Settlement Agreement specifies that a juvenile mortality/survival study will be conducted. This study would be conducted after installation of the new runners for the purpose of determining juvenile losses (Federal Energy Regulatory Commission 1990). A previous study that estimated turbine mortality at Wells was conducted in 1980 shortly before the turbine breakdown occurred (Parametrix 1986). The

Wells turbines are operated using a computerized control system that automatically adjusts the turbines to the best efficiency for any given load and head conditions.

Juvenile Bypass System

The Wells smolt bypass system began its formal existence in 1987 when the Mid-Columbia Coordinating Committee agreed to replace fish passage spill with bypass system spill. In 1989, the full-scale bypass system was in operation. In 1990, the smolt bypass system began operating under the terms and conditions of the Wells Dam Settlement Agreement (Federal Energy Regulatory Commission 1990).

The design of the juvenile bypass system is based largely on a series of studies conducted by DCPUD between 1980 and 1989 addressing both biological and technical concerns. The sequence of studies followed a logical progression which frequently built upon the findings from previous years, as evidenced in the following summary of study objectives (Johnson et al. 1992):

- 1980 to 1983: determine the vertical, horizontal, and diel distribution of smolts immediately upstream of the dam and monitor run timing;
- 1983 to 1986: determine the most efficient bypass baffle configuration;
- 1986: evaluate the effects on bypass efficiency when adjacent bypass units are operating;
- 1987: determine the most effective locations for bypass units; and
- 1988 and 1989: determine the statistical relationship between passage at various locations.

Study methodology included both fixed-location hydroacoustic sampling and direct capture of smolts by fyke netting. Based on the results of these studies, the Wells dam juvenile bypass system was designed and installed as described in Sections 2.3.3 and 2.3.4 of this report. The juvenile bypass system has operated every year since 1990 in accordance with the operational and timing criteria of the 1990 Wells Dam Settlement Agreement. During the first three years of operation (1990 to 1992), an FPE evaluation program was implemented, again in accordance with the settlement agreement.

Bypass flows required to operate the juvenile bypass system are noted in Figure 3-2, which presents the average percent of flow as spill for the past five years at Wells. Virtually all spill was used to operate the bypass system, as there was no significant amount of forced spill from 1990 through 1994. The highest bypass flows occur from April through July.

Figure 3-2. Average percent of monthly flow spilled at Wells dam from 1990-1994.
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Fish Production As Mitigation

As part of the Wells Dam Settlement Agreement, the DCPUD is funding a hatchery-based compensation program to mitigate for fish passage losses at Wells dam, in addition to its existing Wells fish hatchery program. For purposes of the settlement agreement, the total project mortality for juvenile salmon migrants at the Wells Project, including both dam passage and reservoir mortality, was estimated to be 14 percent (Federal Energy Regulatory Commission 1990). Steelhead mortality was not specifically estimated in the settlement agreement, and the parties agreed to continue steelhead production programs and plans initiated under previous mid-Columbia settlements (Federal Energy Regulatory Commission 1990).

The amount of fish production required as compensation is determined by a formula using a five-year running average of adult runs by species. Since 1991, the DCPUD has been operating in Phase 1 of the program, which establishes the following mitigation goals:

- 49,200 lbs of stream-type chinook yearlings at about 15/lb;
- 8,000 lbs of sockeye juveniles at about 25/lb; and
- 30,000 lbs of steelhead smolts at about 6/lb.

Based on the adult run results, Phase 2 will either expand the sockeye program or eliminate sockeye production and add production of ocean-type chinook juveniles. The compensation level may also be adjusted following completion of a project juvenile mortality/survival study, to reflect the differences between the mortality rate developed in the study and the 14 percent mortality rate assumed in developing original production amounts. Adjustments may also be made to compensate for unavoidable and unmitigated adult losses (Federal Energy Regulatory Commission 1990).

The DCPUD began implementation of the Phase 1 production plan in 1990 with a decision by the Joint Fisheries Parties to conduct the steelhead program at its existing Wells fish hatchery and to construct new facilities for the stream-type chinook and experimental sockeye programs. The Methow hatchery and its satellite sites were completed in 1992 to accommodate the stream-type chinook program, with physical facilities that include three adult collection sites, a central hatchery facility, and two acclimation facilities. The DCPUD also constructed the Cassimer Bar hatchery as an experimental facility.

Effectiveness of Existing Mitigation

Turbine Improvements and Operations

Installation of the high-efficiency turbine runners at Wells dam was completed in 1990, and there have been no turbine mortality studies conducted since that time. A study conducted at Wells dam in 1980 estimated turbine mortality at 16 percent (Parametrix 1986). The turbine runners in place at that time had lower peak efficiencies and larger clearances between the blade and the discharge ring and between the blade and the hub. It is not possible at present to provide a direct measure of the effectiveness of turbine improvements and operations.

Juvenile Bypass System

During 1990 through 1992, the fish passage efficiency (FPE) of the juvenile bypass system was measured for each spring and summer migration period as specified in the Wells Dam Settlement Agreement. Each year, the results exceeded the performance criteria of 80 percent FPE in spring and 70 percent FPE in summer. An arithmetic average of the three years of FPE measurements is shown below along with the standard errors and 90 percent confidence interval estimates (Skalski 1993) (Table 3-2).

Table 3-2. Fish passage efficiency of the smolt bypass system for spring and summer: 1990-1992.

Season	**Average FPE**	**Standard Error**	**90% Confidence Interval**
Spring	89.4%	3.10%	80.4% to 95.5%
Summer	89.0%	6.32%	70.5% to 100%

Source: Skalski 1993.

An arithmetic average of the annual FPEs is believed to provide a more realistic indicator of future performance of the bypass system, as compared to a weighted average. The weighted average FPEs were 92.4 percent for spring and 96.4 percent for summer (Skalski 1993).

The Wells dam juvenile bypass system is being operated in accordance with the terms of the settlement agreement, including the performance criteria. Less than 10 percent of downstream migrants pass through the turbines during the spring and summer migration periods. The small amount of spill used to operate the juvenile bypass system at Wells dam has not been identified as contributing to dissolved gas supersaturation problems below the project (see Sections 3.3.1 and 4.3.1). The system is very effective in minimizing the impact of downstream dam passage on migrants.

Fish Production As Compensation

The hatchery-based compensation program developed as mitigation for losses of juvenile migrants is being conducted as specified in the 1990 Wells Settlement Agreement. The first releases of stream-type chinook from Methow hatchery and its associated acclimation ponds occurred in 1993. The sockeye facilities at the experimental Cassimer Bar hatchery are currently in the evaluation period. The programmed release of 30,000 pounds of steelhead from Wells fish hatchery first occurred in 1991.

Ongoing Monitoring

<u>Wells Project Total Mortality/Survival Study</u>

This study is specified in the settlement agreement and has not yet been conducted. Results of this study will be compared against the 14 percent mortality estimate assumed in the settlement agreement and may be used to adjust the compensation level of fish production.

<u>Annual Passage Monitoring Plan</u>

Each year the DCPUD develops a plan for monitoring juvenile fish passage and presents it to the Wells Project Coordinating Committee for review and approval. The plan includes development of indices of relative fish abundance on a daily basis during seasonal migration periods and provides annual estimates of juvenile migrant production. These items are used to guide decisions regarding operation of the bypass system and to evaluate adjustments to the hatchery-based compensation levels (Federal Energy Regulatory Commission 1990).

<u>Spillway Passage Conditions</u>

Safe conditions for spillway passage are monitored through a dissolved gas monitoring program. Further details of this program are provided in Section 3.3.1.

<u>Production Plan Evaluation</u>

The DCPUD is funding the Joint Fishery Party (JFP) to develop and conduct studies to evaluate the effectiveness of the hatchery-based compensation program and the associated production plan. The studies will meet standards developed for similar efforts under the NPPC's Columbia River Basin Fish and Wildlife Program. Studies anticipated as part of these efforts include the following (Federal Energy Regulatory Commission 1990):

- Marking of juvenile fish and recoveries of juvenile and adult fish to estimate parameters such as fish health, fishery contribution and survival;
- determination of the success to produce the intended compensation level;
- evaluations of modifications to the production plan, if such modifications are

approved by the Joint Fishery Parties; and

- analysis of annual fish production and adult contribution to harvest and escapement.

3.2.2 Downstream Reservoir Passage

Adverse effects of reservoirs on outmigrating juvenile salmonids are thought to be much less of an influence than passage issues at dams. Iwamoto et al. (1994) and Muir et al. (1995) indicated that virtually all of the mortality measured in the mainstem Snake River was attributed mainly to fish passing through the hydroelectric structures and that the reservoirs themselves were quite benign.

Reservoir impoundment can create increased rearing area and provide overwintering habitat for juvenile anadromous salmonids. It can also affect the outmigration of anadromous salmonid juveniles by causing residualization, extended travel times and decreased survival rates. The use of the term "extended travel times" refers to slower rates of travel by outmigrating juvenile anadromous salmonids. Juveniles, when exposed to extended travel times and increased water temperatures, can residualize (become residents) and fail to migrate to the ocean. The following section describes background information on reservoir-related effects of delay and mortality. Information on predation, a major cause of mortality, is covered in Section 3.5 of this document.

<u>Extended Travel Time</u>

Raymond (1968, 1969, 1979) and Bently and Raymond (1976) estimated that juvenile anadromous salmonids move through the Snake River and lower Columbia River impoundments one-half to one-third slower than they would through free-flowing river sections of the same length. According to Raymond (1979) juvenile steelhead and chinook migrate through free-flowing stretches of river at 14 miles per day, while they move through impounded waters at 5 miles per day. Fielder and Peven (1986) found similar rates (3-6 miles per day) for stream- and ocean-type chinook and steelhead juveniles in the mid-Columbia reservoirs.

The rapid flushing rate of Wells reservoir appears to influence juvenile migration, and average reservoir migration time through Wells reservoir appears to be rapid. Movement from the mouths of respective tributaries through Wells reservoir takes only 1 to 2 days for all species. Stream-type chinook salmon released from Winthrop take 2 to 7 days, steelhead from 15 miles up the Methow take 2 to 3 days and sockeye released 1 mile up the Okanogan take 1 to 2 days to reach Wells dam. The median migration speed of ocean-type chinook salmon at Wells fish hatchery arriving at McNary dam ranged from 4.4 to 10 miles/day from 1984 to 1992 (Chapman et al. 1994b).

Berggren and Filardo (1993) found travel time through the mid-Columbia reach was related to prevailing river discharge volume and water temperature. Travel time decreased as temperatures increased at a fixed flow volume. The predicted average water particle travel for the entire 142 miles of the mid-Columbia reach is 8.6 days, or about 16.5 miles per day. Although several studies indicated that water velocity is a primary determinant of juvenile migration speed (Smith 1982; Buettner and Brimmer 1995; Berggren and Filardo 1993) other studies suggest factors other than flow may be affecting the dynamics of out-migration (Achord et al. 1994; Beeman and Rondorf 1992; Mains and Smith 1964; Chapman et al. 1994a).

Sims and Ossiander (1981) reported stream-type chinook and steelhead survival improved with increasing flow through the lower Columbia and Snake River impoundments. However, there is little evidence to suggest that increased flows will increase survival in the mid-Columbia. This is particularly true for ocean-type chinook salmon in the mid-Columbia (Chapman et al. 1994a). Chapman et al. (1994b) measured the travel time and migration speed of freeze-branded subyearling chinook traveling from the Wells dam tailrace to McNary dam. They found no obvious relationship between migration speed and prevailing flow volumes over a broad range of flows.

Delayed Migration

Increase migration times can affect the size and survival rate of juveniles, timing of ocean transition and thermal imprinting. Increased migration times can cause migrating juveniles, especially steelhead, to revert to parr. Laboratory evidence suggests that water temperatures in excess of 20°C for about 20 days, or delaying migration beyond the end of June, may cause steelhead smolts to revert to parr (Chapman et al. 1994b; Adams et al. 1975; Wagner 1974; Zaugg 1981). Some reverted parr residualize and are lost to anadromous production.

According to Poe (1992) the primary mechanism responsible for juvenile mortality associated with downstream reservoir migration is predation by piscivores. Migrational delay due to reservoir effects increases potential exposure time to predatory fish, particularly for ocean-type chinook salmon (Chapman et al. 1994a). Attempts have been made to apportion juvenile downstream migration mortality between dam and reservoir passage. Chapman et al. (1994a) state that reservoir-passage mortality for juvenile stream-type chinook has been estimated at 5 to 10 percent, and that the majority of reservoir-related mortality appears to occur in the downstream vicinity of dams where predatory fish congregate. Muir et al. (1995) estimated total passage survival to be 92 percent from Silcott Island, upper Lower Granite pool, to the tailrace of Lower Granite Dam; 82 percent from the tailrace of Lower Granite to the tailrace of Little Goose Dam; and 88 percent from the tailrace of Little Goose to the tailrace of Lower Monumental Dam. The authors did not attempt to apportion stream-type juvenile downstream migration mortality between the dam and reservoir. However, this Snake River work indicates that reservoir-passage mortality of stream-type juveniles may be much lower than previously estimated. Predation-related mortality of juvenile migrants is addressed in greater detail in Section 3.5.

Survival

Juvenile survival through Wells reservoir has not been directly assessed to date, and there is little information on the relative impacts of interrelated factors such as delayed migration, residualization and predation-related mortality. McKenzie et al. (1984a, 1984b) conducted a multiple-year study to estimate the survival of spring chinook migrants through the mid-Columbia River reach (Table 3-3). Mean survival estimates from Pateros to the Priest Rapids dam tailrace in 1982 and 1983 were 44 percent and 45 percent, respectively. The single project survival rate for Wells, Rocky Reach and Rock Island dams, was 88 percent in 1982 and 83 percent in 1983, assuming survival associated with each of these three projects is constant (Table 3-3). Reservoir mortality could not be separated from direct and indirect sources of mortality through this section of river for the two years studied.

Table 3-3. Summary statistics for system-wide and single-project survival rates.

	Survival Rates (%)[1]					
River[1] Section	**Mean**	**Std Error[2]**	**Var[3]**	**95% C.I.**	**Single Project[4]**	**Avg.**
Pateros to RI[2]	64.04	4.28		50.41-77.67	86.83	
Pateros to RI[3]	59.85		0.0090	51.00-68.69	84.27	85.6
RI to PR[2]	64.52	6.09		45.16-83.89	83.27	
RI to PR[3]	75.21		0.0021	72.59-77.83	86.72	85.0
Pateros to PR[2]	44.12	1.87		38.13-50.06	NA	
Pateros to PR[3]	44.92		0.0058	38.92-50.92		

[1] RI = Rock Island, PR = Priest Rapids, Pateros is about 0.6 miles up the Methow River
[2] Data from McKenzie et al. (1984a)
[3] Data from McKenzie et al. (1984b)
[4] Assuming equal mortality associated with each project

3.3 WATER QUALITY

3.3.1 Dissolved Gas Supersaturation

Existing Issues

Total dissolved gas (TDG) supersaturation is a condition that occurs in natural waters when atmospheric gases are forced into solution at pressures exceeding the pressure of the over-lying atmosphere. Columbia River TDG supersaturation often occurs during periods of high runoff and spill at hydropower facilities, primarily because spill in deep tailrace pools can cause significant entrainment of gases during deep plunge and turbulence of the water. Total dissolved gas supersaturation conditions can persist and accumulate through the mid-Columbia River reach, since the reach consists of relatively calm pools behind each dam, providing less effective dissipation than naturally turbulent river systems. Fish and other aquatic organisms that are exposed to excessive TDG supersaturation can develop gas bubble trauma (GBT); a condition that is harmful and often fatal.

<u>Total Dissolved Gas in the Vicinity of the Wells Project</u>

Total dissolved gas supersaturation is monitored at the Wells Project as part of the Columbia and Snake Rivers Dissolved Gas Monitoring Program conducted by the USACE (1994). Monitoring occurs during the fish migration season, April through September. Data are collected every hour and transmitted every four hours via satellite to the USACE North Pacific Division Headquarters. These data are then compiled, along with pertinent flow, spill and water temperature information, and posted on the Columbia River Operational Hydromet Management System (CROHMS). The CROHMS is used for real-time review by authorized users and potential system spill adjustment recommendations.

Total dissolved gas at Wells is monitored in the forebay of the project. Data have been collected since 1983 at the Wells forebay station by the DCPUD (U.S. Army Corps of Engineers 1994). Daily average TDG measurements at the Chief Joseph, Wells and Rocky Reach dam forebay monitoring stations from 1984 to 1994 generally exceeded 100 percent and, therefore, were consistently in a supersaturated condition during the April to September monitoring period. In general, daily average TDG levels most commonly ranged between 105 and 112 percent during 1984 to 1994 (U.S. Army Corps of Engineers 1994). The maximum observed TDG levels were 125 percent, 126 percent and 132 percent, respectively, at the Chief Joseph, Wells and Rocky Reach dam forebay stations. Such maximum levels could cause serious GBT effects depending on duration, species/life stage differences and other conditions, such as depth and water temperature (Ebel et al. 1975).

Total dissolved gas levels at Wells dam are primarily determined by TDG levels in water passing from Chief Joseph dam. Correlation of TDG data from the Chief Joseph and Wells forebay stations indicates that

TDG levels at the two sites do not differ significantly (U.S. Army Corps of Engineers 1992, 1993). This suggests that TDG is neither significantly increased nor dissipated from spill at Chief Joseph dam and subsequent flow through Wells reservoir. Spill at Wells dam appears to increase TDG somewhat. An examination of daily TDG in 1994 from the Wells and Rocky Reach forebays indicates that an increase in TDG occurred at times between the stations, particularly during periods of relatively high spill at Wells dam (Figure 3-3).

Evidence of GBT in the Vicinity of the Wells Project

Site-specific monitoring in the vicinity of the Wells Project to date has suggested that the incidence of GBT has been minor. The DCPUD co-sponsored a study of GBT symptoms on fish in the five mid-Columbia project pools during the 1974 spill season of May-August (Dell et al. 1975). Total dissolved gas level during the study averaged about 119 percent (ranges from 112% to 131%) in the Wells forebay and about 120 percent (ranges from 111% to 132%) in the Rocky Reach forebay. Chief Joseph dam spilled an average of 38 percent of total river flow during the study (April through August 1974) up to a maximum of 56 percent of total river flow during June (U.S. Army Corps of Engineers 1995d). All fish were examined externally for gas bubbles under the skin, in the fins, on the body and in the mouth and eyes. Evidence of GBT was observed in 2.8 percent and 3.6 percent of the fish examined in the Wells and Rocky Reach pools, respectively.

Information on the depth distributions of migrating salmonids at the Wells Project are described in Section 3.2. Juvenile salmon that migrate in deep water and then move rapidly toward the surface are more susceptible to GBT in waters with high TDG supersaturation (Ebel et al. 1975). Total dissolved gas supersaturation has also been known to cause adult delay at the fishways at other Columbia River projects (Ebel et al. 1975).

Project-specific Measures for TDG Supersaturation Abatement at Wells

No project-specific measures have been initiated for TDG supersaturation abatement at Wells. The 1994 DFOP, which includes comprehensive recommendations for operation of Columbia River mainstem projects for protection and enhancement of fish resources, provided a general system-wide strategy for TDG supersaturation management. The DFOP recommends managing spill by monitoring TDG supersaturation and possible related GBT symptoms in juvenile and adult salmonids during migration periods. Dissolved gas management and control at Wells are provided by DCPUD criteria and will result in spill requests derived from TDG monitoring at the Wells forebay, the observed condition of migrant juveniles and adults and juvenile passage monitoring data. The DCPUD did not provide specific project operating criteria for, and are not bound by, the terms and conditions contained in the 1994 DFOP. However, the DCPUD does participate in the system-wide strategy for TDG supersaturation management and abatement. Spill request management guidelines are described in more detail in Section 2.4.4 of this document.

Figure 3-3. TDG at Wells and Rocky Reach forebays, and spill at Wells dam during April to September 1994

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Effectiveness of Current Measures

No project-specific TDG supersaturation management measures have been required to date at Wells, except for TDG monitoring. The Wells Project does not appear to contribute to an increase in TDG supersaturation during periods of low to moderate levels of spill at the dam. The effectiveness of TDG supersaturation-management under high levels of spill at Wells dam cannot be measured, since spill levels during the juvenile migration period have been low to moderate since 1983.

Current operations are considered effective at avoiding significant increases in TDG and GBT incidence in the project area. Reasons for this effectiveness are due to key features of the project's hydrocombine structure and operation, including:

- Wells has less frequent and lower amounts of spill than at conventional projects (see Section 2.4.1). The project is very effective at passing smolts at relatively small amounts of spill (see Section 3.2.1). Since TDG is related to the magnitude of spill, lower amounts of spill at Wells minimizes increases in TDG.

- The project has a relatively high spillway discharge per unit width. All of the spillway gates release water through the bottom near tailrace elevation level. The spillway has an ogee design with a spillway crest that is only 5.5 feet above normal tailwater elevation (see Section 2.3.1). These design features help keep spillway discharge turbulence at the surface, and avoid deep plunge and gas entrainment that can cause high TDG levels.

Ongoing Monitoring Efforts

Total dissolved gas monitoring occurs in the Wells dam forebay, the Chief Joseph dam forebay and the Rocky Reach dam forebay. Other pertinent information are also monitored, including water temperature, turbidity, total river flow, turbine discharge and spill discharge. It is intended that the TDG monitoring program be somewhat adaptive, i.e., additional coverage and types of data may be warranted as ongoing information is obtained and analyzed. Also, the onset and effects of GBT are still incompletely understood and remain controversial. Adjustments to ongoing monitoring and spill management guidelines could occur pending further biological and physical findings into GBT causes and effects. Juvenile salmonids are routinely monitored for external GBT symptoms as part of the Fish Passage Center's Smolt Monitoring Program at selected Snake and Columbia River dams, but only at Rock Island dam in the mid-Columbia region.

3.3.2 Water Temperature

Existing Issues and Concerns

The potential effect of dams on water temperatures on the Columbia River depends on the extent of river impoundment and regulation at hydropower facilities. Such regulation can alter the natural heating and cooling of the river, subsequently affecting salmonids' incidence of disease, timing of migrations, maturation of spawners, time of incubation and hatching, and levels of dissolved oxygen and TDG (Bonneville Power Administration et al. 1994a; Chapman et al. 1994a; Dauble and Mueller 1993).

<u>Water Temperature Conditions in the Vicinity of the Wells Project</u>

Water temperature monitoring has been conducted from 1984 through 1994 by the DCPUD in conjunction with TDG monitoring at the Wells facility. As with the TDG data, water temperature data are obtained from approximately April through September each year. Water temperature and TDG data are collected manually every four hours and transmitted via teletype to the USACE CROHMS database.

Data collected at the Wells forebay station may not accurately reflect the water temperature of the entire volume of water passing the Wells dam. The temperature probe is stationary so the depth below the surface varies with the elevation of the pool. Because some warming of the surface layer is likely, especially near the dam, this fluctuation in the water surface elevation may result in temperature measurements higher than the majority of the water passing the Wells dam (Parker, pers. comm., 27 January 1995).

Water temperature at Wells dam forebay during 1994 is presented in Figure 3-4. Water temperature does not appear to substantially increase from Chief Joseph dam to Wells dam (U.S. Army Corps of Engineers 1993). Comparison of water temperatures recorded at Chief Joseph dam and Wells dam during the last 11 years indicates that water can either warm or cool between the two facilities (U.S. Army Corps of Engineers 1993). Water temperatures at the Wells forebay can exceed 18°C during July, and a maximum of about 20°C is reached in August and September. The maximum water temperature recorded, 22.3°C, occurred during August 1984 (U.S. Army Corps of Engineers 1993). By comparison, summertime water temperatures at Chief Joseph dam also commonly exceed 18°C and usually are within a few tenths of a degree of the temperatures at Wells (U.S. Army Corps of Engineers 1993). Furthermore, temperatures measured at Chief Joseph are occasionally higher than at Wells. A maximum temperature of 23.0°C was recorded during August 1984 at Chief Joseph dam (U.S. Army Corps of Engineers 1993).

Figure 3-4. Water temperature measured in the forebay of Wells dam in 1994
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The lack of a consistent thermal effect between Chief Joseph dam and Wells dam suggests that substantial heat exchange does not occur as water travels through Wells reservoir. As a run-of-river reservoir, Wells reservoir has a rapid flushing rate, ranging from hours to a few days.

Reservoirs with rapid flushing rates have a mostly river-like character, including weak and intermittent or non-existent thermal stratification (Johnson et al. 1978; Kimmel and Groeger 1984; Cox 1984). In addition, rapidly flushed pools often do not permit substantial heat input and concomitant water temperature increases in pool outflow.

Evidence of Effects on Salmonids in the Vicinity of the Wells Project

Currently no problems associated with water temperature are being observed at the Wells facility (Hevlin, pers. comm., 27 January 1995; Woodin, pers. comm., 26 January 1995). The WDOE segment of the Columbia River affected by the Wells facility (Chief Joseph dam to Priest Rapids dam) is not on the Clean Water Act Section 303(d) list as being water quality limited for temperature. However, EPA has cited water temperature as a concern from Bonneville dam to Chief Joseph dam (Bonneville Power Administration et al. 1994a). Monitoring data from the mid-Columbia River reach near Wells dam indicate that water temperatures commonly exceed the 18°C water temperature standard during July, August and September. Moreover, water temperatures measured at Wells dam have exceeded levels shown to cause delays in upstream migration and have exceeded criteria set by the NPPC for some species (Table 3-4).

Table 3-4. Water Temperature criteria for salmon and steelhead (°C).

Species	Upstream Migration	Spawning	Incubation	Preferred	Optimum	Upper Lethal
Chinook						
Fall (ocean-type)	11-19	6-14	5-14	7-14	12.00	25.00
Spring (stream-type)	3-13	6-14	5-14	7-14	12.00	25.00
Summer (ocean-type_	13-20	6-14	5-14	7-14	12.00	25.00
Steelhead	-	4-9	-	7-14	10.00	24.00
Sockeye	7-16	11-12	-	11-14	-	-

Source: NPPC 1992a

Some problems associated with high water temperatures have been observed in the past. High water temperatures in the spawning channel (see Section 2.3.4 for a description of this facility) caused pre-spawning mortality of adults and post-spawning mortality of eggs (Woodin, pers. comm., 26 January 1995). Water for the spawning channel was taken directly from the Wells forebay. These temperature-related problems were a major cause of the failure of the spawning channel.

Mitigation and Monitoring Measures

No mitigation has been directed specifically toward dealing with any water temperature problems. However, monitoring is conducted annually by the DCPUD in conjunction with the dissolved gas monitoring as described above.

The potential for improving water temperatures within the mid-Columbia River reach, including in Wells reservoir, is limited. Augmentation releases in the summer from Lake Roosevelt at Grand Coulee dam could perhaps decrease water temperatures in waters flowing into Wells reservoir. Lake Roosevelt is large and deep enough to stratify and provide a source of cold water during summertime. However, Grand Coulee does not currently have selective withdrawal capability to release waters at depth from Lake Roosevelt to reliably accomplish decreases in water temperature (Bonneville Power Administration et al. 1994a).

Effectiveness of Mitigation

For salmonids or other aquatic plants and animals, no obvious effects due to water temperature have been observed at Wells dam. However, within the Columbia River adverse effects of high water temperatures have been noted for sockeye in the Okanogan River upstream of Wells dam. Within the river, no effects (e.g., mortalities and reductions to spawning success) have been observed, although such effects are difficult to document. In addition, no effects have been observed at Wells while temperature-related problems have been observed at other facilities on the Columbia and Snake Rivers during the same time period.

3.4 RESERVOIR PRODUCTION

Creation of Wells reservoir in 1967 impacted potential spawning and rearing fish habitat in a 30-mile reach of the Columbia River. Inundation of the river created a pool with slower velocities and greater depths than present under free-flowing conditions. The effect of these physical changes on the fish community in the mid-Columbia reach varies by life stage and species.

3.4.1 Spawning Habitat

Existing Concerns and Issues

The Wells Project reach primarily supports rearing and limited spawning of the fall component of summer/fall chinook. The project reach also serves as a migration corridor for other species of anadromous fish. Prior to inundation of Wells pool, Meekin (1967) documented spawning of chinook in the Columbia River, primarily between Brewster and Washburn Island on Buena Bar where groundwater upwelling occurred. He also noted chinook spawning to depths of 30 feet at and around Bridgeport Bar and Washburn Island and shallow areas below Chief Joseph dam. Shortly after pool development, Meekin (1967) indicated that mainstem spawning may have continued in the Brewster Bar area. Other surveyors have suggested that potential spawning occurs near Bridgeport Bar, Washburn Island, in areas of substantial groundwater upwelling in the pool (Hillman and Miller 1994; Chapman et al. 1994a; Stuehrenberg et al. 1995), and they have documented spawning in the Wells tailrace (Giorgi 1992). Members of the Colville tribe have also noted some deep water spawning activity near Washburn Island (Bickford 1994). Fall chinook salmon have been found to spawn in deepwater reservoir habitat in the mid-Columbia River (Meekin 1967; Chapman and Welsh 1979; Giorgi 1992; Dauble et al. 1994). Stuehrenberg et al. (1995) last recorded 18 percent (7 of 40) of the adult fall chinook passing Wells dam in the Bridgeport Bar area. It is possible some or all of these fish used Wells reservoir for spawning. One adult was last tracked in the Okanogan River mouth, and may have spawned there. Four adults were tracked to the Chief Joseph dam tailrace (two were caught in the fishery there), and seven adults were last tracked in Wells reservoir, near Wells dam (Stuehrenberg et al. 1995). It is unknown whether or not these adults spawned successfully.

Fall (ocean-type) chinook salmon spawning in the tailrace of Wells dam has been well documented (Giorgi 1992; Peven 1992). Peven (1992) summarized aerial redd surveys for the area from Rocky Reach dam to Wells dam; redd counts are highly variable, and range from zero in about half the years to a maximum of 302 for the period from 1956 to 1991. The WDF (now part of WDFW) first observed six fall chinook redds in the Wells tailrace in 1967. Surveys observed between six and 57 redds in the Wells tailrace from 1967 until 1973 (Peven 1992). The reappearance of spawning chinook adults in the Wells tailrace area coincided with the discontinuance of trapping operations at Rocky Reach dam for the spawning channel (Chelan County Public Utility District 1991c). After 1973, redd counts below Wells dam decreased, ranging from zero to three redds per year until 1987. Since 1987, fall chinook redds have been consistently observed with peak counts exceeding 100 per year (Peven 1992).

The two major tributaries to Wells reservoir, the Methow and Okanogan Rivers, both contain suitable spawning habitat. Little potential spawning habitat is available in the smaller tributaries. Most of the smaller tributaries flow only during precipitation events or transport irrigation return-flows during the irrigation season. Adult spring, summer and fall chinook are known to spawn only in these two tributaries to Wells reservoir.

Tributary Bedload and Fine Sediment Deposition

No data about deposition of fine sediment in Wells pool are available. It is likely that smoothing of the hydrograph and lack of significant reservoir fluctuation have increased the amount of fines present in the substrate, especially in the lower portion of the reservoir. Suspected mainstem spawning by fall chinook salmon is concentrated between Washburn Island and Chief Joseph dam primarily because the river hydraulics are sufficient to maintain well-sorted substrates relatively free of fines (Bickford 1994). Tributary inflow into Wells reservoir is limited primarily to the Methow and Okanogan River drainages. Alluvial deltas have formed at the confluence of the Methow and especially the Okanogan Rivers. Fine sediment loading in both these tributaries is considered high, although the fine sediment load in the Methow River is less than in the Okanogan River. The alluvial fan at the mouth of the Okanogan River is comprised of mostly medium- to fine-grained sand and silt (Rensel 1993). The deposition area is regarded by some researchers as a mud flat (Bickford 1994). The area near the mouth of the Methow is composed of coarse-grained sand (Rensel 1993).

Because the majority of suspected fall chinook salmon spawning sites in the reservoir are located upstream of the Okanogan River, changes in sediment deposition near tributary junctions will not decrease the existing spawning production potential. Deposition of tributary bedload could provide a source of substrate for potential spawning habitat near the mouths of tributaries but such increased spawning has not been documented in Wells reservoir. Irrigation return flow in the smaller tributaries occurs from March through October and primarily transports fine sediments to Wells reservoir.

Previous and Existing Mitigation Measures

Existing mitigation for losses of mainstem spawning habitat due to inundation by Wells reservoir has been stipulated in the Wells project operating license No. 2149. The agreement specifies hatchery fish production to compensate for spawning losses (see Section 2.3.4).

Effectiveness of Existing Mitigation Measures

Section 3.6 discusses the effectiveness of existing hatchery-based mitigation for spawning or spawning habitat losses due to the existence of the Wells Project.

Ongoing monitoring

No ongoing monitoring of spawning or spawning habitat is conducted in the Wells Project area.

3.4.2 Rearing Habitat

Existing Issues

Reservoir Conditions

The Wells Project area includes the tailrace, extending approximately 1,000 feet below Wells dam, and Wells reservoir (Lake Pateros), a 30-mile long reservoir upstream of Wells dam. The upper end of the reservoir extends to approximately 2,000 feet below Chief Joseph dam. The lake has a total surface area of 10,280 acres, a volume of 350,000 acre-feet, and an average depth of 34 feet. Water temperature ranges from just above 0.6 to 20°C, and the pool does not thermally stratify during summer due to its relatively high flushing rate. Wells reservoir also has the third highest flushing rate of the mid-Columbia reservoirs (Zook 1983). Although Wells reservoir has 100 miles of shoreline, most of the shoreline is steep, and the proportion of littoral area in the reservoir is small in comparison to its size. Due to the presence of a number of islands and inundation of two major tributary mouths, the ratio of shoreline length to reservoir length of 3.3:1 is the highest of the mid-Columbia reservoirs. Rapid water exchange, a relatively featureless shoreline and lack of riparian habitat severely limit juvenile salmonid rearing. Although there is an abundance of rocky and rip-rapped shoreline areas, there is little backwater habitat suitable for warmwater species, with the exception of the mouth of the Okanogan River. The majority of the reservoir shoreline remains undeveloped, but riparian habitat adjacent to the reservoir is sparse.

Factors with the potential to affect the rearing capacity of the reservoir include its flushing rate, the thermal regime, the degree of primary and secondary productivity, the level of submerged macrophyte growth, deposition of fine sediment, benthic organic matter, water quality conditions and fluctuating water levels in the reservoir. Very little information specific to Wells pool regarding these factors is available.

Reservoir Flushing and Turnover Rate

Water retention time, or flushing rate, of Wells reservoir ranges from 14 hours during spring runoff (June) to approximately 4.6 days in February, with an annual average turnover rate of 2.5 days. This water turnover rate is considered rapid in comparison to lower mainstem and mid-Columbia River reservoirs.

Nutrients, Aquatic Productivity, Zooplankton Abundance

No specific information related to productivity of Wells reservoir is available. Most of the primary and secondary production potential in the mid-Columbia region, however, is generated from upstream sources due to the slow turnover rate, large storage capacity and source of nutrients. Lake Roosevelt (upstream of Grand Coulee dam) is the single most important factor influencing aquatic productivity in the downstream PUD reservoirs (Rensel 1993).

The thermal regime of the mid-Columbia River is also influenced by realeases from Grand Coulee dam, which has the largest storage capacity of any reservoir on the U.S. portion of the Columbia River system. Lake Roosevelt exhibits strong thermal stratification during summer months. Since Grand Coulee dam is not equipped with selective depth-withdrawal facilities, downstream water temperatures are heavily dependent on the depth of the Lake Roosevelt thermocline.

The flow-through characteristics of the mid-Columbia dam reservoirs result in primary productivity being largely dependent on detritus, sessile (attached) algae and macrophytes (Mullan 1986). The turnover time of water in the pool is too short in summer to permit development of extensive and diverse zooplankton communities. Therefore, productivity may limit available prey items for juvenile anadromous salmonids in the mid-Columbia reservoirs (Rondorf and Gray 1987).

Submerged Macrophytes

Submergent aquatic plants are abundant in Wells reservoir. The benthic community in these submerged macrophyte beds is probably increasing as riverine macrophytes effectively create their own substrate. Substrate is created by velocity reduction and subsequent particle trapping which encourages settling of organic-rich soils (Falter et al. 1991). In the area upstream of Brewster, reduced current velocity and substrate type encourages the growth of macrophytes. Eurasian watermilfoil (*Myriophyllum spicatum*) is found there (Rensel 1993). Macrophyte beds eventually increase the production of benthic food organisms, and provide surfaces where algae and invertebrates will live. They may also provide cover for rearing juvenile salmonids and other fish species.

Fluctuating Water Levels in Wells Reservoir and Potential for Fish Stranding

Wells reservoir generally consists of steep morphologies along the river margins with limited backwater and shallow areas. The areas around the tributary confluences and near islands offer the greatest potential for stranding fish. No studies or evidence of stranding fish are available for Wells reservoir. Daily drafting of up to several feet at Wells dam is a relatively slow process and does not represent a large stranding concern for juvenile fishes.

Deposition of Tributary Bedload and Fine Sediment, Rearing Effects

Reduction of peak flows and lack of significant water level fluctuation in Wells reservoir have probably increased the amount of fines present in the cobble substrate, especially in the lower portion of the reservoir. Substrates are still cleansed to a limited extent between Washburn Island and Chief Joseph dam (Bickford 1994). Rearing habitat for most mid-Columbia fishes may be concentrated in the upper section of the reservoir primarily because of the availability of shallow water habitat and substrates free of fines.

Water Quality

There is no indication that the Wells Project is having an adverse effect on water quality parameters that would reduce the reservoir rearing production potential. See Section 3.3 of this document for discussions of water quality in the mid-Columbia River and its effects on rearing habitat.

Status of In-Stream Rearing in Wells Reservoir

The importance of mainstem reservoir habitat for rearing of mid-Columbia fishes varies by species. It is generally believed that stream-type migrants tend to migrate rapidly through the reservoir in mid-channel, exhibiting little or no reservoir rearing time (Ledgerwood et al. 1991b; Zook 1983).

Ocean-type chinook salmon use nearshore littoral habitat in the reservoir for rearing for a much greater period of time than stream-type migrants (Chapman et al. 1994a; Burley and Poe 1994). Chapman et al. (1994a) cite hydroacoustic and fyke net data that showed high ocean-type chinook juvenile passage rates at Wells dam beginning in late June and continuing through early August in most years. No specific data regarding ocean-type chinook rearing in Wells reservoir have been collected to date. Chapman et al. (1994a) cites use of "more open water (deep pools), near woody debris wherever it was available, and close to boulder rip-rap at the stream margins" by ocean-type chinook juveniles in the Wenatchee, Methow, and Okanogan Rivers from July through September. It would be expected that ocean-type chinook juveniles rearing in Wells reservoir would seek similar habitat.

Ocean-type chinook salmon juveniles use the mainstem reservoirs for rearing in late spring and early summer (Chapman et al. 1994a; Burley and Poe 1994). Recently emerged ocean-type chinook juveniles rear throughout the shallow, low velocity areas of the reservoirs in April and May. After reaching approximately 50 mm in size, they move slightly offshore into faster flowing water and typically establish feeding territories along the river bottom (Campbell and Eddy 1988; Rondorf and Gray 1987; Hillman et al. 1988; Chapman et al. 1994a). Chinook may sight feed on limnetic species when available, but prefer benthic macroinvertebrates in the drift when rearing (Chapman et al. 1994a). Based on these criteria, it appears that most suitable chinook rearing habitat is found in the upstream portions of the reservoirs, where river velocities are greater and the substrates area coarser (less fine sediment) than downstream in the reservoirs. However, no surveys have been done in the mid-Columbia reservoirs to determine habitat preferences and rearing areas of ocean-type chinook salmon.

Ninety percent of the steelhead rearing production occurs in hatcheries (Chapman et al 1994c). The balance of the rearing production occurs in the tributaries, although some minor amount of reservoir rearing may occur during overwintering.

Although sockeye could conceivable rear in the reservoirs, the rapid flushing rate, low primary productivity and lack of abundant zooplankton limit production potential. The Wells pool may be a source of rearing habitat for the small but sustained run of Methow River sockeye (Bickford 1994; Chapman et al. 1995b).

Previous and Existing Mitigation Measures

Full and complete mitigation for all spawning and rearing habitat modifications due to reservoir impoundment at the Wells Project has been made through the FERC project license and in the 1990 Settlement Agreement (Federal Energy Regulatory Commission 1990). The license articles include hatchery-based mitigation for assumed reservoir losses. According to the agreements, the loss of spawning and rearing habitat has been fully mitigated by hatchery production.

Ongoing Monitoring

There is no current or proposed monitoring of rearing habitat in the Wells Project reach.

3.5 PREDATION

The following section describes the risk of juvenile outmigrant mortality due to predation at the Wells Project and DCPUD efforts designed to improve outmigrant survival. Discussion of potential predation on juvenile outmigrants at the mid-Columbia PUD projects involves use of the terms tailrace, forebay and mid-reservoir areas. Throughout the HCP project document, the term forebay and mid-reservoir refer to areas upstream of the project dam. Tailrace will refer to the area immediately below the project dam. For instance, the Wells tailrace area is located immediately below the Wells dam at RM 515 and extends downstream for approximately 1,000 feet. The boat-restricted zone (BRZ) refers to areas above and below the dam where conditions present a danger to recreational boaters.

3.5.1 Status of Predator Populations

Northern Squawfish

Northern squawfish, a large, native predatory fish are abundant in the Wells Project area and are under consideration as a potentially significant source of juvenile outmigrant mortality. In a 1993 survey conducted by the WDFW to assess the significance of predation, 337 northern squawfish were captured over 12 days of sampling at Wells (Burley and Poe 1994). Northern squawfish accounted for approximately 95 percent during the spring sampling period and 84 percent during the summer sampling period of all predators caught in the Wells dam project area (Table 3-5). In a study conducted from 1983 to 1986 at a lower Columbia River dam, salmonids accounted for 21 percent of the diet of 300 mm northern squawfish and 83 percent of the diet of larger squawfish (Poe et al. 1991). The size of salmonids consumed by northern squawfish also increases progressively with the size of the squawfish. The northern squawfish caught by the WDFW at Wells averaged 332 mm in length. Squawfish of that size are capable of consuming salmonid juveniles up to 155 mm long (Poe et al. 1991).

Table 3-5. Number of predatory fish caught at the Wells Project site during a 1993 WDFW survey.

	Spring	
Species	**Number**	**Percent of Total Catch**
Northern Squawfish	105	94.6
Walleye	3	2.7
Smallmouth Bass	3	2.7
	Summer	
Northern Squawfish	232	84.1
Walleye	18	6.5
Smallmouth Bass	26	9.4

Source: Burley and Poe 1994.

Northern squawfish prefer areas of slow water velocity, especially where low velocity borders high-velocity areas (Faler et al. 1988). Such sites are common in the Wells tailrace. Previous studies have documented high concentrations of northern squawfish in dam tailraces on the lower Columbia, and attributed such concentration to the existence of low velocity refuges near sites which frequently contain large numbers of injured or disoriented prey fish (Beamesderfer and Rieman 1991; Poe et al. 1991). In 1993, predation indexing studies conducted by the WDFW and National Biological Survey (NBS) found that the density of northern squawfish at the Wells Project was highest in the tailrace-BRZ (Loch et al. 1994).

Northern squawfish catch in the tailrace boating restricted zone (BRZ) at Wells dam may have been influenced by release of ocean-type chinook juveniles from the Wells fish hatchery just prior to sampling (Sauter et al. 1994). Ocean-type chinook juveniles were released from the hatchery and flushed into a small spawning channel below the dam. A relatively large number of squawfish were caught in the spawning channel, 93 percent of the total tailrace-BRZ catch, which may reflect a feeding response by the squawfish to the hatchery release. However, Consumption Index values were lower than and gut contents similar to other mid-Columbia River project tailraces sampled (Sauter et al. 1994). The authors theorize that ocean-type chinook juveniles, as well as other prey species, may have sought out quieter water in the spawning channel area, created by strong currents flowing from the tailrace, thus providing greater feeding opportunity for squawfish (Sauter et al. 1994).

Smallmouth Bass

Smallmouth bass were the second most abundant predatory fish species captured at the Wells Project during the 1993 WDFW survey (Burley and Poe 1994). Four smallmouth bass were taken at Wells over six days of sampling in the spring (Table 3-4), and 36 were captured over six days of late summer sampling. Most smallmouth bass were captured in the Wells tailrace area, but nearly one-third were captured at mid-reservoir sites. Based on studies conducted in the lower Columbia River (Tabor et al. 1993), smallmouth bass appear to selectively feed on ocean-type chinook salmon. Ocean-type chinook outmigrate and rear along the reservoir shoreline and are preyed on by smallmouth bass that inhabit those areas.

Smallmouth bass are not known to reproduce in Wells reservoir, probably due to water temperature limitations (Zook 1983). Water temperatures in Wells reservoir are typically lower than those preferred by smallmouth bass (Wydoski and Whitney 1979) in areas containing suitable spawning substrate. Preferred spawning temperatures for this species range from 16 to 18°C (Wydoski and Whitney 1979; Scott and Crossman 1973); such temperatures consistently occur only in August and September in the Wells reach. A rise in river flow and associated decrease in water temperature during spawning season will cause adult bass to abandon their nests and has been linked to the periodic total loss of annual production in the lower mid-Columbia reach (Zook 1983). Despite the lack of suitable spawning conditions in Wells reservoir, habitat for adult smallmouth bass is plentiful. Adult fish prefer rocky shoals and moderate depths (Scott and Crossman 1973), and are well adapted to low productivity, flowing water habitat such as that found in Wells reservoir. Smallmouth bass inhabiting Wells reservoir are presumed to have been recruited from the Okanogan River, where a population is well established and expanding (Zook 1983).

Walleye

Walleye are piscivorous gamefish introduced into the upper Columbia basin to support recreational fishing. Twenty-seven walleye were captured during the 1993 WDFW survey at Wells compared to 40 at Rock Island, 24 at Rocky Reach, 18 at Wanapum and 13 at Priest Rapids. Eighty-nine percent of the walleye caught at Wells were taken in the tailrace (Burley and Poe 1994). Concentrations of walleye observed in the tailraces of the mid-Columbia projects may represent either spawning runs (Brown and Williams 1985) or a feeding response to the concentrations of vulnerable salmonids and resident fishes in the tailrace (Burley and Poe 1994).

Despite the presence of walleye in the Wells tailrace, which may represent a spawning run, there is no direct evidence that walleye are successfully reproducing in the Wells Project area (Zook 1983). Bennett (1991) suggested that the two factors most limiting walleye recruitment in the mid-Columbia River were low turbidity and a lack of juvenile rearing habitat. Walleye require shallow, highly productive backwater areas for rearing. Because of the short water retention times and precipitous shorelines, the Wells reservoir lacks sites with warm, quiet water and abundant plankton production (Zook 1983). Walleye currently inhabiting Wells reservoir are believed to have originated upstream in Lake Roosevelt, and have been carried downstream to Wells reservoir during spring high flows. During the late 1970s, the Wells tailrace was the site of the most active walleye fishery in the mid-Columbia. The fishery declined abruptly in 1981, and this decline was attributed to overexploitation of a walleye stock with a low rate of recruitment (Brown and Williams 1985). Length distribution of sport-caught walleye revealed an absence of immature fish, supporting the hypothesis that the reproductive success of walleye in the mid-Columbia is limited.

No specific dietary data were available for walleye captured in the Wells Project area during a 1993 National Biological Survey (NBS) study (Burley and Poe 1994). A study of walleye food habits at the John Day reservoir in the lower Columbia River suggested that salmonids consistently accounted for only about 18 to 24 percent of the walleye diet there, even when juvenile outmigrants were abundant and highly concentrated in areas occupied by walleye (Poe et al. 1991).

The walleye's apparent inability to reproduce successfully in the mid-Columbia reach precludes the threat of population explosion and serious salmonid predation (Brown and Williams 1985). Should the population of walleye at Wells substantially increase, however, this species could impact survival of the juvenile outmigrants passing the project.

In summary, because of their number, fecundity and behavior of targeting outmigrating juvenile salmonids as a food source, northern squawfish are the primary predator of concern at the Wells Project (Burley and Poe 1994). Smallmouth bass and walleye are not numerous in Wells reservoir, resulting in minimal predation of juvenile outmigrants. Smallmouth bass may pose a notable risk to subyearling chinook because the subyearlings are a size easily consumed by the bass and they migrate and rear in areas inhabited by the bass.

Gulls

A 1982 study at Wanapum dam, downstream of Wells, indicated that gulls were consuming a substantial number of outmigrating juveniles (Ruggerone 1986). Prior to installation of protective devices, ring-billed gulls consumed an estimated 2 percent of all juvenile salmonids passing Wanapum dam. Although site-specific studies were not conducted at Wells, gulls have been observed feeding heavily on juvenile outmigrants in the Wells tailrace. Because of the identification of gulls as a significant predator of downstream migrating juvenile salmonids, the DCPUD has installed gull wires in the Wells dam tailrace. A considerable reduction in gull activity was observed following such installation.

3.5.2 Vulnerability of Juvenile Salmonids to Predation

Several million juvenile salmonid outmigrants pass through the Wells Project area each year (Fish Passage Center 1994). Concentrations of outmigrating salmonids are common in the dam forebay and in the tailrace area below the dam. Some young fish may be disoriented or injured passing the dam, making them more susceptible to predation.

Tailrace

Downstream migrating fish pass Wells dam either through the turbines, or over modified spillbays. Passage via turbines or spill is known to temporarily stun, or to injure or kill some young fish (Eicher Associates 1987; Muir et al. 1994). Juvenile outmigrants frequently become disoriented in the strong, turbulent currents immediately below the dam. These disoriented or injured fish are less adept at escaping predators. Backwater eddies downstream of the dam tailraces provide ideal holding areas for northern squawfish which prey upon the disoriented salmonids (Faler et al. 1988). Gulls also show a feeding response to the concentrations of disoriented salmonids in dam tailraces (Ruggerone 1986).

In 1993, the WDFW and NBS assessed predation at the Wells Project and developed consumption, density, abundance and predation indices (Table 3-6) (Burley and Poe 1994). The authors indicated that predation near the tailrace poses the most significant risk to juvenile outmigrants at the Wells Project (Table 3-7). Samples of the gut contents of northern squawfish collected in the tailrace indicated that squawfish were feeding primarily on juvenile salmonids during the spring (Table 3-6) (Loch et al. 1994). The northern squawfish predation index for the Wells tailrace-Boat Restricted Zone (BRZ) was lower than any of the mid-Columbia projects except Rocky Reach in the spring, but was consistent between spring and summer sampling periods (Loch et al. 1994).

Samples of northern squawfish gut contents during the summer suggest that northern squawfish in the tailrace either switch to other food items during the summer or reduce their feeding activity (Loch et al. 1994). Approximately 30 to 40 percent of squawfish sampled near the dam had empty stomachs, and non-salmonid fish accounted for a greater proportion of their diet than in spring (Table 3-7). Squawfish may curtail or reduce feeding activities in June due to spawning behavior (Stein 1979; Helfman 1981).

Table 3-6. Northern squawfish (>250 mm fl) index values for various locations at the Wells Project, 1993.

	Spring			
Project location	**CI[1]**	**DI[2]**	**AI[3]**	**PI[4]**
Tailrace	0.5	1.528	0.42	0.21
Tailrace - BRZ[5]	-	1.472	0.07	0.03
Forebay	0.5	1.194	0.37	0.18
Forebay - BRZ[5]	0.4	1.472	0.02	0.01
Mid-reservoir	0.2	1.112	2.05	0.61
	Summer			
Project location	**CI[1]**	**DI[2]**	**AI[3]**	**PI[4]**
Tailrace	0.5	1.528	0.42	0.21
Tailrace - BRZ[5]	1.5	1.472	0.07	0.10
Forebay	0.1	1.194	0.37	0.04
Forebay - BRZ[5]	0.0	1.472	0.02	0.00
Mid-reservoir	0.0	1.112	2.05	0.00

Source: Loch et al. 1994.
[1]Consumption Index = Number of organisms consumed per day by an individual predator
[2]Density Index = Estimated number of predators per sample area (The authors did not differentiate density numbers between spring and summer).
[3]Abundance Index = DI * Surface area (The authors did not differentiate abundance estimates between spring and summer).
[4]Predation Index = CI * AI
[5]Values for boating restricted zone only.

Table 3-7. Stomach contents of northern squawfish (> 250 mm fl) caught by electroshocking at the Wells Project during the spring and early summer, 1993.

Spring							
Reservoir Location	**Sampling Date**	**No. of Squawfish**	**% empty guts**	**% fish in diet**	**salmonids as % of prey fish consumed**	**total number of salmonids consumed**	**salmonids as a % of the total diet**
Tailrace	4/22-4/24	40	13	100	100	73	100
Tailrace-BRZ	4/22-4/24	0	-	-	-	-	-
Forebay	4/22-4/23	18	39	88	31	4	27
Forebay-BRZ	4/22-4/23	12	50	78	40	2	31
Mid-reservoir	4/20-4/21	21	29	60	30	3	18
Summer							
Reservoir Location	**Sampling Date**	**No. of Squawfish**	**% empty guts**	**% fish in diet**	**salmonids as % of prey fish consumed**	**total number of salmonids consumed**	**salmonids as a % of the total diet**
Tailrace	6/24-6/25	55	33	36	33	6	12
Tailrace-BRZ	6/24-6/25	18	39	50	60	6	30
Forebay	6/24-6/25	41	37	37	9	1	3
Forebay-BRZ	6/24-6/25	18	28	37	0	0	0
Mid-reservoir	6/22-6/23	18	83	33	0	0	0

Source: Sauter et al. 1994.

Reservoir Forebays

Juvenile salmonids migrating downstream through Wells reservoir may concentrate in the forebay immediately upstream of the dam prior to finding a way through the dam. As in the tailrace areas, northern squawfish and other predators are attracted to such concentrations of juveniles. Density indices of northern squawfish in the Wells forebay sample area during the spring were slightly lower than those observed in the tailrace (Table 3-6) (Loch et al. 1994). Gut sample contents of northern squawfish during the spring indicated that salmonids accounted for a much lower proportion of the squawfish diet than in the tailrace (~ 30% compared to 100%) (Table 3-7). Few salmonids were identified in gut content samples from 23 squawfish sampled in the forebay area in late June. The lack of salmonids in squawfish gut samples during the summer may reflect the fluctuation in timing of salmonids outmigrants.

Mid-reservoir

Predation losses of juvenile salmonids to northern squawfish in the main portion of Wells reservoir appear to be minimal. Northern squawfish were abundant in the mid-reservoir at Wells as compared to some of the other mid-Columbia reservoirs (Burley and Poe 1994). Juvenile salmonids accounted for 18 percent of the northern squawfish gut contents taken from the mid-reservoir at Wells reservoir during the spring, but were not found in any of the gut contents of northern squawfish in the summer of 1993. No concentrations of prey or predators were observed at the mid-reservoir sites. The relative scarcity of salmonids contained in the gut contents of northern squawfish taken from the mid-reservoir, as compared to the tailrace and forebay, suggests that juvenile salmon may be more adept at avoiding northern squawfish away from the dam site.

In summary, the greatest risk of juvenile outmigrant mortality due to predation at the Wells Project occurs in the tailrace. The concentration and disorientation during dam passage makes juvenile outmigrants particularly susceptible to predation at this site. Concentrations of outmigrating salmonids may be exposed to potential predation in the forebay, but predators do not appear to target the juvenile salmonids as successfully in this area. Based on existing information, predation in mid-reservoir appears to be low in Wells reservoir.

3.5.3 Existing Mitigation Measures

At present, mitigation measures implemented to reduce predation at the Wells Project are installation of wires across the tailrace-BRZ and implementation of a squawfish removal program to prevent gulls and squawfish from feeding on juvenile salmonids. No specific data are available on the effectiveness of the gull wires at Wells dam, but Ruggerone (1986) suggested that such measures could reduce consumption of juvenile salmonids significantly in areas protected by wires based on studies conducted at Wanapum dam. Occasionally gulls learn to navigate through the wires and periodic hazing is conducted to frighten gulls away from the tailrace area.

The DCPUD contacted with the USDA in 1995 to extend gull wires farther downstream in the tailrace area. The wires were extended from a "pivot point" on the east bank near the earth fill area across the river to the west shore in a radial fashion. The new gull wires extend an additional 400 feet downstream and increase the tailrace area covered by wires from nine acres to 17 acres (Klinge, pers. comm., 21 September 1995).

The DCPUD also instituted a pilot squawfish program for removal at Wells dam in 1995. Squawfish were removed from the tailrace and Wells fish hatchery release area via gillnets and angling with hook-and-line in an attempt to reduce predation-related mortality on downstream migrating juvenile salmonids. Results of the program were not as great as expected in 1995. Modifications were implemented in 1996 to increase the effectiveness of the squawfish removal program.

3.5.4 Ongoing Mitigation Efforts

No program for monitoring anadromous salmonid loss due to predation is being conducted at this time.

3.6 TRIBUTARY HABITAT STATUS AND IMPROVEMENT OPPORTUNITIES

The following information concerning an assessment of tributary habitat in the Methow and Okanogan Rivers is a summary from Bugert et al. (1997).

3.6.1 Methow River Watershed

The Methow River supports several populations of "Plan Fish Species" . Ocean type chinook spawn only in the mainstem Methow River, between French Creek and the confluence with the Chewuch River. Stream-type spring chinook spawn primarily in the mainstem Methow River upstream of the confluence with the Chewuch River, and in major tributaries including the Twisp River, Chewuch River and Lost Creek (Hubble and Sexauer 1994). Based on redd counts, the average natural escapement to the Methow River (including both wild and hatchery fish) has dropped from 3,429 for the period 1960-1969 to 772 for the period 1990-1995. Spring chinook spawn in the Twisp River, the Chewuch River between Boulder Creek and Lake Creek, in Lake Creek, and in a small section near the mouth of Thirtymile Creek. Escapements over the last 3 decades (1964-1973, 1974-1983, 1984-1993) are estimated to average 505, 384 and 310, respectively (U.S. Forest Service 1995).

Sockeye salmon adults are observed in the Methow River nearly every year (Chapman et al. 1995b). These fish are believed to be strays from the Wenatchee and Okanogan stocks, artifacts from releases of the Winthrop NFH between 1945 and 1958.

The majority of land in the Methow basin (94%) is comprised of public lands managed for multiple use (primarily timber harvest, recreation and grazing). An extensive forest road system has been developed in the Chewuch and Twisp River basins since the 1930s, Roads are frequently located in narrow floodplains, and may impact aquatic habitat through reduced riparian canopy, lost off-channel habitat, reduced pool habitat and increased sediment loads. The USFS estimates that sediment delivery to the Methow system from activities on public lands is only ten percent higher than background. Thus the effect of increased sediment on salmonid production is not assumed to be a major concern.

The remaining land area consists of private holdings. Private lands contain most of the riparian bottomlands accessible to anadromous salmonids. Private lands in the basin are used for home sites, small farms, irrigated agriculture and grazing. Approximately 60 percent of the riparian bottomlands used by livestock have suffered erosion bank sloughing and bank cutting.

Peak flows occur in late spring as the result of snowmelt runoff. Low flows occur in late summer, and dewatering of several reaches of the mainstem Methow and Twisp Rivers has been documented (Northwest Power Planning Council 1990; Caldwell and Catterson 1992; MPP 1994). Dewatered reaches often coincide with areas supporting the highest density of spring chinook redds and rearing juveniles (Hubble and Sexauer 1994). While the dewatering appears to be a natural phenomenon, it is exacerbated by irrigation withdrawals.

The quality of waters in the Methow basin is rated high, with major tributaries meeting Class AA (extraordinary) or Class A (excellent) standards. Water temperatures may occasionally exceed state water quality standards in the summer. Anchor ice development in the winter has also been identified as a potential problem. Four reaches in the lower mainstem Methow and Twisp Rivers were rated as water quality limited [on the state 303(d) list] because of low instream flows.

Habitat in the upper mainstem Methow River has experienced limited impacts from either natural events or logging, grazing and agriculture. The quality of substrate is good (Chapman et al. 1994a). Downstream of the confluence with Chewuch River, agricultural uses predominates on stream adjacent lands, and detrimental impacts have been noted (Washington Department of Wildlife 1993).

Habitat in the Chewuch River has been impacted by channelization and forest harvest. The northeast half of the watershed is relatively undisturbed and functionally intact. Habitat inventories Okanogan National Forest (ONF) indicate that large woody debris (LWD) is deficient in much of the mainstem. The USFS hydrologists believe the low level of woody debris is the result of a combination of stream cleanouts for flood control, salvage of instream wood, and extensive streamside harvest of potential recruitment trees. Portions of the lower Chewuch River have been channelized as a result of bank protection efforts after the 1948 flood.
Habitat inventories conducted by the ONF indicate that LWD is also below standard in much of the

mainstem Twisp River. The highest densities of salmonid production for all species combined has been observed in relatively undisturbed tributary reaches with the slowest moving water (Hubble 1994). These areas contain abundant cover in the form of LWD, boulders and other associated habitat features (Mullan 1994).

It is unclear why the Methow River has smaller runs of summer chinook than other mid-Columbia tributaries (Mullan et al. 1992) In general, the condition of spawning gravels in the lower Methow is good, as is water quality during the majority of the summer chinook rearing residence. There is evidence that some subyearlings remain in the Methow River through summer, and emigrate in fall (Chapman et al. 1994a). If a large component of the populations remains through summer, they may be effected somewhat by irrigation water withdrawals. Irrigation withdrawals may also reduce adult migration, holding, and spawning habitat (Chapman et al. 1994a), and effectively increase summer water temperatures.

The mainstem Methow River and tributaries can be a hostile environment for salmonids during late summer low flows and winter. Stream channel confinement provides adequate depth and cover for salmonids, yet temperatures and flow extremes may cause significant mortality. Lack of riparian cover reduces shade and allows significant loss of thermal insulation in the winter. Much of the spawning and rearing habitat for spring chinook salmon lies upstream from irrigation diversions. However, because it flows through a permeable glacial deposit some reaches may become dewatered. Prespawning mortality may be a significant factor for spring chinook in the Methow (Scribner et al. 1993; Chapman et al. 1995a). Lack of holding cover associated with LWD is one potential cause.

Lack of LWD in the Chewuch and Twisp may also exacerbate the movement of juvenile chinook downstream into areas that may be less suitable for overwintering. However, several authors cite evidence that the quality and quantity of juvenile rearing and adult holding habitat has either remained the same or increased slightly since the 1930s (Mullan et al. 1992; McIntosh et al. 1994).

Recommended strategies to maintain or enhance salmonid habitat in the Methow basin focus first on protection of existing habitat by securing riparian habitat. This protection may be accomplished through conservation easements or direct purchase. Habitat restoration strategies center on maintaining instream flows through renovation of the Methow Valley Irrigation District systems, and support of water conservation measures in tributary diversions. A second goal is to increase the complexity of the stream channel and floodplain by restoring side channel function and restoring riparian habitats.

3.6.2 Okanogan River Watershed

The following paragraphs represent a summary of material contained in the draft report titled "*Aquatic species and habitat assessment: Wenatchee, Entiat, Methow and Okanogan Watersheds"* (Bugert et al. 1997), which is an exhibit to this HCP.

OKANOGAN RIVER

The Okanogan River originates in British Columbia, and flows south through several large lakes before reaching the United States at Lake Osoyoos. Below the lake, the river continues south for approximately 200 km before entering the Columbia River. Major tributaries in the U.S. include the Similkameen River, and Tonasket, Bonaparte, Tunk, Salmon and Omak Creeks. The lower 27 km of the river has been inundated by the pool of the Wells Hydroelectric Project.

The average annual flow of the Okanogan River (measured at Ellisforde, approximately 17 km downstream of Lake Osoyoos) is 3,200 cfs. About 75 percent is contributed by the Similkameen River. Flows in the Okanogan River are regulated by a series of dams in British Columbia, and by Zosel Dam in the U.S. Water releases to meet fishery needs are negotiated yearly by a consortium of fisheries and irrigation managers from the United States and Canada. In 1976, WDOE established base flows for the Okanogan River (WAC 173-549) and ruled that no further appropriation of surface water shall be made which would conflict with these flows.

Major land use activities in the U.S. portion of the Okanogan basin include forestry, mining, agriculture and grazing. Major timber producing lands include the Loomis Forest, managed by the WDNR, and the Okanogan National Forest (ONF). ONF lands in the northwest include part of the Pasayten Wilderness.

The Similkameen River is considered one of the better gold producing streams in the state (Barth and DeMayer 1982). The Washington Department of Natural Resources (WDNR) issues two year leases for the bed and shorelands to private individuals .

Agricultural activities including irrigated croplands, orchards, and livestock wintering grounds predominate in the wide, low gradient valley along the mainstem Okanogan River. Irrigators rely on water from two primary sources: the Similkameen River (approximately 180 cfs during peak season) and the mainstem Okanogan (approximately 33,500 acre feet annually).

The Okanogan River currently supports anadromous runs of chinook salmon, sockeye salmon and steelhead. Upstream passage of anadromous fish is limited by several major barriers. McIntyre Dam, approximately 21 km upstream of Lake Osoyoos, is a barrier to a sockeye migration, although some salmon have been known to pass the dam in high water years (Hansen 1993). Enloe dam, at RK 14 on the Similkameen River, is located at a site of a natural falls that blocks anadromous salmonid access. Other barriers include a diversion dam on Salmon Creek and a velocity barrier on Omak Creek. The dam diverts water from Salmon Creek into an irrigation ditch, dewatering the lower 5 km of the stream except during spring freshets. The velocity barrier is formed where Omak Creek is routed through a large culvert under the Omak Wood Products Mill near the mouth of the creek. Funding to correct the velocity barrier has been obtained by the Colville Confederated Tribes (CCT), and this action is expected to restore natural production to over 60 km of steelhead habitat.

The run strength of ocean-type chinook has declined slightly in the mainstem Okanogan over the last 20 years, and increased slightly in the Similkameen River (Chapman et al. 1994a). Summer chinook spawn in limited areas over approximately 103 km of the mainstem Okanogan between Zosel Dam (at the outlet of Lake Osoyoos) and the town of Malott. On the Similkameen River, summer chinook spawn from Enloe dam to Driscoll Island, a distance of approximately 14 km (Hillman and Ross 1992).

There are no indications that spring chinook salmon currently use the Okanogan drainage. Historical records indicate that they used three areas: Salmon Creek (prior to construction of the diversion dam (Craig and Suomela 1941); tributaries upstream of Lake Osoyoos (Chapman et al. 1995a); and possibly Omak Creek (Fulton 1968).

The run strength of sockeye salmon is highly variable; escapement has ranged from a low of 1,662 in 1994 to a high of 127,857 in 1966 (as measured at Wells Dam). Sockeye salmon spawn upstream of Lake Osoyoos, primarily over an 8 km reach in the mainstem Okanogan River between Lyons Park and McIntyre Dam (Hagen and Grette 1994). Lake Osoyoos is the primary rearing area for sockeye salmon in the Okanogan watershed. The lake is eutrophic, and has an abundant food supply (Rensel 1996).

Few wild steelhead currently use the Okanogan River, and the historical record, while incomplete, suggests that steelhead use has always been low (Mullan et al. 1992). Salmon Creek, Omak Creek and the Similkameen River had small runs of steelhead, but are not used now because of passage barriers on each stream.

The Okanogan River, Similkameen River, Omak Creek and Lake Osoyoos are all on WDOE's 303(d) list of water quality impaired water bodies. Fecal coliform bacteria, total bacteria, pH, temperature and dissolved oxygen levels have all exceeded state and federal water quality criteria. Water temperatures often exceed lethal tolerance levels for salmonids in the lower Okanogan River. This exceedence is due in part to solar radiation on the upstream lakes, but is exacerbated by sedimentation, irrigation withdrawals during summer low flows, and the lack of riparian cover. High temperatures in the summer and fall effectively exclude juvenile salmon from rearing in most of the accessible waters in the basin. High water temperatures in the lower Okanogan River may at times block adult anadromous salmonid passage.

Lake Osoyoos is relatively shallow, very warm in the summer months, and appears to be in the transitory state leading to complete eutrophication (Booth 1969; Allen and Meekin 1980). The warm water temperatures, anoxic hypolimnetic areas and lake dwelling predators may influence sockeye salmon survival in the lake (Pratt et al. 1991).

Sockeye production in the Okanogan system is currently believed to be most limited by spawning habitat (Allen and Meekin 1980; Mullan 1986; Chapman et al. 1995b). Flow reductions in the mainstem upstream of Lake Osoyoos may have serious impacts on incubation survival (Major and Mighell 1966); Mullan (1986) stated that 15,000 more sockeye could spawn in the river if flows were increased from 375 cfs to 470 cfs during spawning, and maintained at that level throughout incubation.

Spawning gravel that remains accessible is severely limited because of sedimentation. Heavy silt loads have caused fines to infiltrate redds, and smother habitat for invertebrates in the Similkameen and lower Okanogan Rivers. High turbidity in these reaches reduces the feeding efficiency of juvenile salmonids. Surface erosion on agricultural bottomlands and mass wasting on adjacent hillslopes were serious problems in the 1970s, but have been reduced by switching crops and adoption of Best Management Practices (BMPs) by USDA. Sedimentation from roads within the forested areas is also a concern.

Unstable banks are also a issue along the mainstem Okanogan River. A 1994 survey by the NRCS indicated that approximately 14.6 km of riverbank between Oroville and Tonasket requires treatment. The OCCD and NRCS recently started collaborative bank stabilization efforts using bioengineering concepts.

Recommended strategies to maintain or enhance salmonid habitat in the Okanogan basin focus on facilitating and funding institutional activities such as BMPs and CRMPs to reduce nonpoint sources of organic pollutants and sediment. Discussions with Canadian authorities on means to improve passage and spawning conditions will be accomplished through the Cooperative River Basin Project, facilitated by the OCCD. Habitat restoration strategies include passage improvements on Salmon and Omak Creeks, and revegetation of eroding banks in important spawning areas.